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Eminent Engineers

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Brief Biographies of Thirty-two of the Inventors and Engineers who did most to further mechanical progress

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By

DWIGHT GODDARD,

Member of American Society of Mechanical Engineers.

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Preface.

These short biographies were originally written from 1903 to 1906 and issued in monthly numbers by Wyman & Gordon, manufacturers of drop forgings, Worcester, Mass. and Cleveland, Ohio.

Some of them have been entirely re-written others enlarged and revised, and others left as originally written.

In the selection of names, those have been included who have accomplished something of importance in the development and application of power and machinery.

For convenience, the book is divided into two parts—European and American.

Cleveland, October 1st, 1905.

List of Americans

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Massachusetts to Georgia. He laid his plans to publish a newspaper, but his rival got the start of him; so he waited until it failed, when he bought it in cheap. Immediately it changed character, and became the first real *news* paper in America. Its pages were enlivened by some of Franklin's best work. He did not hesitate to use its columns for poking fun at high and low, exasperating his competitors and booming his own enterprises. Among the novel features he introduced were advertisements, illustrations, and letters to the editor.

In 1766 he sold out to a partner for a handsome sum. Meanwhile, he had undertaken other business ventures, all of which prospered, till he became one of the rich men of America. As early as 1743 he began to accept public office, and from that time on he was continuously in the public service. He was successively Chairman of Committee of Safety, Colonel of Pennsylvania militia, Burgess to Pennsylvania Assembly, Postmaster of Philadelphia, Deputy Postmaster General for the Colonies, Agent for the Colonies to England, Commissioner to Canada, Commissioner to France, Minister to France, President of Pennsylvania, and in each place he used his very great abilities to expedite public affairs.

Franklin was a many sided man and it is hard to say on which he was the greatest.

Was he most notable as a statesman? It might be. His native good sense, shrewdness and wealth of resource —combined in one eminently genial, tactful, patient and persistent—made him an ideal diplomat. He sought in everything to allay friction and bring about friendly relations.

He was far-seeing in his attitude toward the union of the Colonies, relations with foreign nations, framing

of the Constitution, slavery, taxation and a monetary system, but never sought to force his ideas on others in a way that would leave a sting behind.

As Burgess for Pennsylvania, combating the avaricious claims of the Proprietors; as the energetic Postmaster General for the Colonies; as the conciliatory agent of the Colonies in England, during the increasing perplexities and animosities of the years just preceding the Revolution; as the astute Commissioner to France to negotiate aid and recognition for the rebellious Colonies; as the forbearing first Minister to France; as the first President of Pennsylvania, he stood head and shoulders above his fellow colonials, above all save one—General Washington.

Jefferson said that he had been associated with both these men, and never heard either speak more than ten minutes at a time, and then only on the most important points. John Adams, in one of his fits of littleness, contrasted his own services in Congress, claiming to have been, himself, "active and alert in every branch of business, * * * constantly proposing measures, supporting, * * * opposing, * * * discussing and arguing on every question," with the services of Franklin, who was seen, he says, "from day to day, sitting in silence, a great part of the time fast asleep." Yet Franklin was appointed on every important committee, and Adams on few.

And yet we oftener think of Franklin as a scientist. His particular friends in England and on the Continent were scientists — Hartley, Hume, Herschel, Lavoisier, Priestly.

His letters were read with attention, and printed by the leading scientific societies of England and France.

He was the founder of the American Philosophical Society. He was honored with degrees by Yale, Harvard, St. Andrew's, Edinburgh and Oxford because of his real contributions to scientific knowledge. He discovered in 1743 that storms travel in an opposite direction to the wind. In 1746 he began his investigations of the oneness of magnetism, electricity and lightning, that culminated in his statement of the true nature of electricity, and its positive and negative states. It was quite characteristic of Franklin to turn this knowledge to some useful purpose—of which we shall speak later. His discovery and charting of the Gulf Stream was also appreciated by the scientific world. He first suggested the electrical origin of the aurora, and made original research in regard to sunspots, shooting stars, heat values of different colors, light, heat, fire, air, evaporation, tides, rainfall, geology, wind, whirlwinds, water-spouts, ventilation, sound and ether. He appears to have been in correspondence, at some period of his life, with about every scientist of note of his generation.

As has been said, he inherited mechanical faculties from a long line of blacksmith ancestors. As a printer's apprentice he had exceptional training under the most skillful English craftsmen, and learned also the art of making ink, engraving and type-casting.

In later years his printing-office won a high reputation for the excellence of its product. He made the first copper-plate press seen in this country, and experimented with stereotyping.

He was a natural mechanic, and in his scientific letters he often speaks of "little machines that I have made." He made very many little inventions, but, as he made no

effort to perfect them and did not believe in patents, it is natural that little came of most of them.

We will therefore speak only of a few of the more important. It was quite characteristic of Franklin to turn every observation to some practical use. Thus, when he observed the great waste of fuel in the open fire-places of his day, he proposed to have the heat, after ascending, to descend and heat the surrounding air before entering the chimney. From this came the now well-known Franklin stove, which has for over a century and a half heated our homes with a saving of three-quarters of the fuel.

Again, when experimenting to prove the oneness of electricity and lightning, he thought also how to prevent the danger from descending lightning, and invented the now universally-used lightning rod.

After observing the experiment of bringing music from glass tumblers partially filled with water, he designed his famous "harmonica," that was more curious and musical than useful.

When the cook threw greasy water overboard, all on board might have seen the effect it produced on the wake of the ship, but it was Franklin alone that grasped its significance and proposed to the world the possibility of using oil during times of tempest, to quiet the violence of the waves.

Then there was the proposal that he made to use copper plates to print on china. Before Argand made his lamp, Franklin had constructed a lamp with a pipe in the midst, "which supplied fresh and cool air to the lights."

He read that the Chinese divided the holds of their boats into separate chambers by tightly-caulked partitions, and at once suggested the advisability of doing the same in our larger ships. He drew up a plan for fire-

proofing a house. He invented double spectacles for distance and reading. He constructed a novel clock. He suggested improvements in letter-copying presses and printing presses. Washington writes of "visiting a machine at Dr. Franklin's (called a mangle) for pressing, in place of ironing clothes from the wash."

And yet some of us always think of Franklin as a writer. Here again his many-sidedness is baffling. Was he best revealed as a humorist? Certainly his Poor Richard's proverbs have been most widely printed, even to this day, of American writings. Franklin easily takes his place as the first of that captivating company of American humorists—witty, sane, true, cheering—that our own ever-refreshing Mr. Dooley shows to be still with us.

Some of his best works from a literary point of view were his short essays, written during his latter years in France, for the entertainment of his friends. He was better revealed, however, in his journalistic writings, which began when he was sixteen and for fifty years made him the dread of his political opponents. His facility with words, ready satire and keen sense of humor made him a tower of strength to whatever cause he espoused.

Then his letters were eagerly sought, and whether political, business, social or philosophical, were models of their kind—clear, logical, convincing, brilliant, always cheerful and good-humored.

His autobiography was one of the most popular ever written. His philosophical and scientific papers were always straightforward, luminous and informing.

He avoided drafting state papers, wrote only one book and few long essays, and yet he was unquestionably the foremost American writer of his age.

Together these qualities and faculties made him the

greatest man of America even to this day, worthy to be classed with the greatest of all time.

Physically he was about five feet ten inches high and quite stout. By nature he was inclined to be indolent, and self-indulgent. He was far from being a saint, but his rare good sense kept him from excess.

He was born in 1705, and died in 1790. He had lived a long life in a genial, generous, useful fashion, permitting a rare good sense to be the handmaid of a warm love for his fellow men. He closed it as he himself had sung six years before the summons came:

"If Life's compared to a Feast,
Near Four-score Years I've been a Guest,
I've been regaled with the best,
And feel quite satisfyd.
'Tis time that I retire to Rest;
Landlord, I thank you!—Friends, Good Night."

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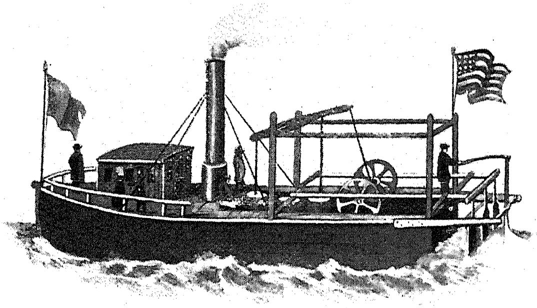

Fitch's Steamboat 1790

John Fitch.

1743-1798

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In the latter years of his life John Fitch looked back on an incident of his childhood as a harbinger of the ill-luck that persistently followed him to his grave.

He was only five years old when left alone in the house with his younger sister. She accidently set fire to a bundle of flax. John, seeing it afire, although it was pretty heavy, tugged it to the fireplace and then ran after the second bundle and dragged that to the fireplace and stamped on it until it was extinguished, thus saving the house and his little sister. He was badly burned, and while still smarting his older brother came in and without a word of enquiry, boxed his ears and beat him

severely. When his father returned later he also gave another beating. Certainly his whole life is a story of hard experience, whether we call it luck or see in it a natural cause and effect.

John was born in 1743 at Windsor, Conn. His father was a stern, close man, typical of New England, who wasted no outward show of affection on his children. At ten he was taken from school and set to work on the farm. He had a strong desire for learning, and young as he was worked overtime to get money with which to buy a geography. At twelve he had learned a little of surveying. At thirteen he received the grudging consent of his father to go to school for a few months more. At this time he learned some more surveying. Then he went back to farm work, had a few months before the mast, and then started in to learn the trade of a clockmaker.

His usual hard luck attended him, and after three years he purchased his freedom, having been kept almost entirely at farming, with a smattering of general brasswork, but in total ignorance of clock or watch making.

Then he had a run of good luck, went into brasswork on a capital of twenty shillings, and in two years had paid all his debts, had fifty pounds ahead, and had learned to clean clocks.

Then hard luck set in again. He went into the manufacture of potash, that interfered with his brass business, took him to another part of the State, and ultimately ruined him. To make it doubly unfortunate, it brought him in contact with the one who became his wife. She proved to be a scold, and made his life so unbearable that he finally closed up his affairs and left her forever.

For some months he roamed about as an itinerant

laborer, passing from Albany to New York and Trenton. Here he learned to make brass buttons and silversmith's work. When trade was dull, he set out peddling brass buttons, and did well. Then opportunity offering he bought "the finest set of silversmith tools in America," and began making silver and brass buttons in quantity with such success that at the breaking out of the Revolution he was worth 800 pounds.

Being an earnest patriot he sought military appointment, but was set aside for other men. He found plenty of work as armorer for the State of New Jersey until the British approached, when he left with others. For several years he followed the American army as a peddler, bringing supplies from the cities to the army. He made a good deal of money at this, but it being in paper currency and depreciating rapidly, he invested it in Western land warrants. Then to insure these investments he secured an appointment of deputy surveyor, and went to Kentucky, and located his lands. In 1782 he made a second trip down the Ohio, but was captured by the Indians, and lost all his property. He endured much suffering for several months, and was then in the hands of the British for months more. While with them, with his usual industry, he cultivated a garden and began to make brass buttons.

When captured he had kept possession of an engraver's tool, and with this made other tools, until he had a vise, lathe and forge. With these tools he made brass and silver buttons, clocks, and repaired watches.

After his release he was forty days en route to New York, and about penniless. At this time the disposition of the Northwest lands was being considered. Fitch, from his knowledge of the region, felt that a good profit might be made from a pre-survey. He formed a company, and

in three seasons roughly surveyed over 200,000 acres. Congress finally disposed of the land in such a way that he had no advantage from his pre-survey.

In 1785 he had his first idea of a steam wagon, but after trying for a week to draft one, he gave it up for what seemed to him the more feasible plan of a boat propelled by steam. At this time he had never seen, and, as he avers, never heard of a steam engine. In a few weeks' time he had completed his plans, and showed them to his friend, Rev. Mr. Irwin, who produced a book from his library giving a description of a Watt engine. It came as a surprise to Fitch, who had supposed himself to be the inventor of the steam engine as well as the steamboat. At first he was "very much chagrined," but set to work to make a working model. The model was made and tried about July, 1785. It worked all right, but the small paddle-wheel being relatively deep in the water lost much power.

After spending more time on his experiments he began seeking aid from individuals and Congress, but to little purpose. Sept. 27, 1785, he presented to the American Philosophical Society a full description and model of his boat. In this model he employed an endless chain with blades on it passing over rolls on the sides of the boat. He sought assistance from Franklin, but received none, and in a short time Franklin presented a paper himself to the Philosophical Society, in which he suggested using steam to propel boats. Franklin's plan was to pump water from the front and discharge, under pressure, at the stern.

During the winter of 1785-86 Fitch sought state assistance from Washington, Virginia, Maryland, Pennsylvania, New Jersey, and Delaware. He received encour-

agement, but no financial aid. It was during these journeys that he heard of Rumsey, but as his was a mechanical boat and not a steamboat, he felt no uneasiness.

In the spring of 1786 he heard that one Donaldson, to whom he had shown his plans, claimed to have invented a steamboat and was going to apply to the State of Pennsylvania for exclusive rights. Angered at this, Fitch at once applied for exclusive rights, and was fortunate in getting in his application first. Without waiting he hurried to New Jersey, and made the same application, which was granted. Then Fitch set to work to form a company to build a steamboat, in which he was successful. The next difficulty was to construct a steam engine. There were at this time only three in the country, and they were old atmospheric engines, used for pumping out mines.

After trying to find some one capable of making one, Fitch decided to make it himself, with the aid of Henry Voight, an ingenious watch-maker. They first made a model cylinder one inch in diameter. Then they made one of three inches. They bought a skiff and tried various devices—"a screw of paddles," an endless chain, and one or two other modes—that worked indifferently. Then Fitch thought of a series of paddles, operated by cranks, that worked very well, and when the engine was applied, moved the skiff at a satisfactory speed.

It was then decided to build a larger boat with a twelve-inch cylinder. In spite of the success with the model, money came very slowly and Fitch again tried to get assistance from the State. Although he failed in this, he did succeed, in 1787, in getting exclusive rights to use steam and fire for the propulsion of boats in Pennsylvania, Delaware and New York.

With this encouragement the larger engine was be-

gun. The drawings and full description of this engine have been lost or destroyed, but Fitch used steam at both ends of the cylinder, and employed a separate jet condenser with air pump. It is interesting to note that Watt secured his patent for a double-acting engine in 1782, but did not make a second engine on that principle until 1787, which is the same year in which Fitch made this larger engine for his steamboat.

While they had the correct idea, they were ignorant of the correct proportions, and that which followed showed how much they were embarrassed.

After a long series of mishaps, the boat was tried, Aug. 22, 1787, in the presence of most of the convention for framing a Federal Constitution. The boat went about forty miles at the rate of three or four miles an hour, somewhat less than was expected. It was enough, however, to encourage another attempt.

Just at this time Rumsey appeared and claimed that his mechanical boat of 1784 was operated by steam, and sought to secure the rights already granted to Fitch. Then followed a most vexatious fight of words that lasted for years. Rumsey had considerable money and influence on his side, and Fitch was almost alone, having only a company of discouraged stockholders to back him up. The fight went on with disheartening slowness and indefiniteness.

In 1788, in the midst of this discouragement, it was decided to build a larger boat. After no end of trouble, it was decided to use the old twelve-inch cylinder, and a pipe boiler on a narrower boat, with one set of oars only at the stern. The discouragements continued: more of the stockholders dropped out, others interfered with the design of the machinery, and Fitch became very irasci-

ble. He was treated as an importunate visionary, laughed at by street loafers, and avoided by men of means. Still he kept at it; in rags and desperation. The costly experiments went on, the boat caught fire, and at last the river froze up and stopped work for the winter of 1789. In the spring of 1790 the boiler was changed, and other alterations made, but without success. At last Fitch made up his mind that the trouble was in the condenser and made a proposal to improve it. His suggestion was treated with scant consideration, but finally assented to. The result was gratifying. April 16, 1790, the boat was tried in the face of high winds, and went "amazingly swift." For the first time the public journals condescended to notice the invention.

The boat was run frequently to Burlington at a speed of seven and eight miles an hour. After June she made regular trips until winter set in, covering no less than 2,000 miles. At times, she made as much as nine and ten miles an hour. On one day she made ninety miles, at an average with and against the tide of seven and a half miles an hour.

Fulton was unable to meet this record in the "Clermont" seventeen years later.

During the fall of 1790 every effort was made to build a second steamboat in order to save their exclusive rights to the waters of Virginia and the Northwest. They almost succeeded, but a violent storm wrecked their boat at the point of completion.

During the winter of 1790-91 the legal sparring for patent rights went on and new troubles among the stockholders made the life of Fitch miserable.

While they were waiting the tardy action of the patent commissioners, it was decided to sell rights in France.

The patent was granted to Fitch Aug. 26, 1791, but almost duplicate patents were granted at the same time tc Rumsey—with intimations that they were at liberty to fight it out in the courts.

Although spasmodic efforts were made to complete the new boat, the prospect of continued lawsuits and the mishaps of experimental construction dampened the ardor of the stockholders, until one after another lost interest.

By September the boat was completed, but the wooden case of the boiler leaked so badly that the effort was a failure. Then Fitch, now in extreme poverty, made all manner of desperate efforts to raise money to complete the boat, but all his efforts ended in disappointment. He became almost a monomaniac, and in 1792 seriously considered suicide. In anticipation of this event, he prepared a detailed account of his life and the history of the steamboat, which he deposited with the Philadelphia Library, with instructions that it was not to be opened for thirty years after his death.

Here ends the history of the Philadelphia boats, except the fact that the materials were sold at auction in 1795.

In 1793 Fitch was sent to France in connection with the sale of the French rights, but being unsuccessful he left the drawings and specifications with the American consul, Vail, and came home (1794) as a sailor. These drawings and specifications were afterward loaned to Robert Fulton, and were in his possession for some months.

Upon his return Fitch made a steamboat out of a ship's yawl. The engine cylinder was of wood, the boiler was an iron pot, but the interesting thing was a horizontal shaft with a vertiable screw propeller at the stern. This was successfully run on a fresh-water pond near the site of the old Tombs prison in New York.

Fitch went from here to Philadelphia, and then to Kentucky to look up his lands. He found them overrun with squatters, and commenced several lawsuits to dispossess them. In extreme poverty and discouragement he deliberately set about self-destruction. In a fit of sickness, sometime in July, 1798, he committed suicide.

In physique he was tall and thin, with black hair and piercing black eyes. He was a man of sterling character, of natural modesty, high integrity, great industry and perserverance. Under the stress of constant misfortune he became garrulous, impatient, passionate and morose—the natural result of continued misfortune upon one who feels his superiority and honesty.

As a mechanic he was rather more ingenious and industrious, than of notable ability. He was a "tinker" rather than an engineer, and it is noticeable that whenever he applied himself to making brass buttons or repairing clocks and guns, he prospered. His so-called hard luck came when he attempted engineering problems that were beyond his abilities or training.

He doubtless should have credit for inventing the steamboat, but it needed a greater man than he to gather up the results of his experiments and those of Symington, Cartwright, Stevens, and others, and by the power of a greater engineering ability, to correctly design and proportion the steamboat that was to survive. For this Fulton should have credit.

There is something pathetic in the discouragement of the one who, failing, yet prophesies that a man more powerful than he will take his ideas and win the honor that he craved and had missed. But that was Fitch's luck to the end.

Nathan Read

1759-1849

From an engraving, the plate for which was made by St. Memin, Phila., 1902

Nathan Read.

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The name of Judge Nathan Read ought not to be omitted from the list of early Americans who made contribution to the beginning of steam locomotion and steam navigation.

Read was a Massachusetts man, born at Warren in 1759, of English ancestry who came to America as early as 1632. His father and wife's uncle were high officers in the Revolutionary Army and he was connected with some of the wealthy and most respected families of his day.

At the age of nineteen years he entered Harvard College, intending to study for the ministry. He became a fine Hebrew scholar and graduated Valedictorian of his class. He was a tutor at Harvard College until 1787, when he left to study medicine.

He tired of medicine in a year and opened an apothecary shop in Salem to which he gave attention until 1795.

It was during these years that his bent for mechanics appeared and apparently he devoted no little time to experiments and building models, especially of boilers and engines for land vehicles and boats. His claim to our attention is due to his inventions at this time and will be considered more in detail later on.

In 1791 he was elected a member of the American Academy of Arts and Sciences. In 1795 he gave up the

apothecary store and removed to his farm in Danvers. In 1796 he, with others, erected the Salem Iron Works for the manufacture of chain, anchors, and other articles of iron for ship building, Read having the chief superintendence. While here he designed and patented in 1798 a machine for cutting and heading nails that gave a good line of business for many years. In 1800 he was appointed a member of Congress and re-elected the following term. In 1802 he was appointed a Special Justice and in 1807 removed to Belfast, Maine, where for many years he was Chief Justice of the Court in Hancock County.

He had a fine farm here of 400 acres and thereafter gave most of his time to agriculture and interest in educational institutions. He never could forget his early taste for mechanics, however, and indulged at frequent intervals in mechanical experiments from which resulted the invention of several useful agricultural implements.

The one thing that Judge Read did in the mechanical line for which he should receive the highest credit was the invention of the multitubular boiler that made the locomotive and the steamboat possible.

As early as 1788, when Read was at his apothecary store, he became interested in the mechanical propulsion of boats and wagons. Others were interested also, but were mainly considering the method of propulsion, with little thought of the source of power other than horses or men. Read fitted out a boat with side wheels on a double crank shaft, running in grooves across the sides of the boat, so placed that he could operate the cranks with his hands instead of oars. He used this boat at Danvers in 1788. At this same time, and the following year, he was experimenting with a steam engine and boiler, which he used on both a boat and a wagon.

Read.

To thoroughly understand and appreciate the novelty of Read's inventions, it will be well to recall what others had done before him and the extent at this time of knowledge about steam and engines.

In England it was only 1782 that Watt had invented double acting steam engines and only one or two years previous to Read's experiments had they become commonly known. Symington secured his first steamboat patent in 1787 and an experimental boat was made the next year. Murdock made his model locomotive in 1784.

In America, Fitch made his first steamboat in 1785 and his second in 1787 and did not actually have one running regular trips until 1790, while the Livingston-Roosevelt-Stevens boat was not made until 1798 and Fulton's "Clermont" did not come until 1807, twenty years after Read's experiments.

Fitch's experiments were made with a single tube boiler set in brick. His engine used steam at both ends but he was able to obtain steam of only eight to ten pounds and used a cumbersome condenser.

Read heard of his experiments and made up his mind that if steam navigation was to be a success this outfit must be reduced radically in weight. As a result of his study, he built a model of a vertical multitubular boiler to be made of copper or iron with 78 tubes arranged in circles. The outside rows of tubes were open top and bottom and the inner rows were shorter and open only at the top, the space thus left at the bottom served as a firebox. There was a double shell with a hole in the bottom where the grate was placed.

The water filled the tubes and space between the shells and was supplied from a supplementary tank placed above the boiler which could be filled and closed, when the

connection to the boiler could be opened so that the water would pass to the boiler by gravitation. The flame passed among the tubes and by a flue through the upper space between the double shells and through the water tank to preheat the supply. When we recall the exceedingly heavy and crude boilers made of brick and castings which were used by Watt, Fitch and all others we appreciate what an advance was this portable boiler of Read's.

In addition to the advantage of its lightness, it at once made it possible to secure steam of high pressure. Fitch and others were only able to secure eight to ten pounds pressure while Read advocated and was able to supply steam of 15 to 20 pounds pressure and thus made a source of energy that was practical for use on boats and wagons without a condenser.

He also made a model of a high pressure engine taking steam at both ends and designed to run either with or without a condenser. His first models included a boat with paddle wheels on a shaft on which there were two gears, designed to be operated by flexible teeth spanning the gear and engaging the top and bottom of the gears alternately as the piston moved back and forth. The paddle wheels could be raised and lowered as the boat was loaded or empty.

There are some grounds for believing that he proposed to use the simple crank connection also—as he certainly used them for hand power.

Having the endorsement of the Academy of Science and a number of prominent men, Read went to New York in 1790 to apply for Government assistance and monopoly. He found there seeking the same ends, Fitch, Rumsey and Stevens. The discussions that arose resulted in the passage of the first national patent law. Read discovered in

reading French records that side wheels had already been proposed in France and being under the conviction that his application must contain only novel devices, he re-wrote his application, substituting a chain of paddles running over shafts placed fore and aft, the lower section in the water to propel the boat and the returning section being above and entirely out of water. When his first application was read before Congress the proposal to apply the invention to land carriages provoked so much ridicule that Read omitted that claim in his revised application.

Congress, in 1791, as we all know, granted patents to all four, Fitch, Rumsey, Read, and Stevens, with permission to fight it out in the courts if they were found to conflict.

Fitch's patent was for applying the force of steam for propelling a boat by forcing water through a tube, and to cranks and paddles.

Rumsey's was for the same and for an improved method of generating steam by passing a small quantity of water through an incurvated tube placed in a furnace, both for boats, and every species of engines and for raising water. Stevens' patent was much the same as Rumsey's.

Read's patent was for his multitubular boiler, improved cylinder, and a boat with chain wheels.

It is thus seen that while Fitch, Rumsey, and Stevens were granted patents that involved mutual interference, the patent of Read did not clash with the others.

Had Read made the same effort to bring his patent into actual use as did the others, he would doubtless have succeeded where they failed, for he was a good engineer and when success did come in later years to Fulton for the steamboat, and to Stevenson for the locomotive, in

each case the successful device was the multitubular boiler and the high pressure cylinder that Read had invented. How slow was the evolution, is seen in the fact, that 16 years elapsed after Read's patent was granted, before Fulton's "Clermont" made its successful trip, and 38 years before the multitubular boiler was first applied to the locomotive in Stevenson's Rocket, which alone was successful in the Rainhill trial.

Judge Read lived on for many years, but evidently made no great effort to put his inventions to practical use. His easy going nature, his comfortable circumstances, and even his uncommonly good education hade him less inclined to cope with the obstacles that lay in the path of the successful introduction of the steamboat and locomotive a generation before the times were ready to receive them. Even Fitch's tremendous earnestness failed to do it and Stevens' wealth did not avail.

Judge Read had a tall fine figure with an intellectual face, was modest, and unobtrusive, but active and interested in all that had to do with the higher life of the community. He lived to be ninety years of age, dying in 1849, but retained to the end the full possession of his intellectual powers, and enjoyed to the last the delights of his beautiful estate at Belfast.

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Oliver Evans.

1755-1819

From a rare engraving by W. G. Jackson, in possession of Ridgeway Library, Phil., and Wyman & Gordon, Worcester.

Oliver Evans.

▼ ▼ ▼

Oliver Evans had within him the making of a great engineer. He was born near Newport, Del., in 1755 or 1756, of farmer parentage. At fourteen he was apprenticed to a wheelwright, but continued his eager efforts to secure an education by studying by the light of burning shavings after the long work hours were ended.

While still an apprentice, the idea came to him that there ought to be some way of propelling land carriages without animal power. He gave much thought to it, but made no advance until he heard of the experiment of plugging water in a gun-barrel and exploding it in a forge fire. Evans' active mind saw at once that here was the power he wanted. He met with a book that described the old atmospheric engine. He was astonished to find that they made no use of the elastic force of steam. He went at his problem with renewed ardor, and soon declared to his friends that he could make a steam-carriage, but only met ridicule on every hand. He made many experiments, and persevered for some time, but at last, when his means were exhausted, gave it up for a time.

At twenty-three years of age he invented a machine for making card teeth, but was defrauded of all profit. Soon after he invented a machine for pricking the card, cutting, bending and setting the teeth, but being dis-

couraged from his failure to derive any profit from his first invention, never built one.

At twenty-five he married and went into business with his brothers, who were millers, and who appreciated his mechanical talents. He at once began that series of inventions that ultimately revolutionized the manufacture of flour. His inventions in this line included the grain elevator, the conveyor, the hopper-boy, the drill, and the descender. They effected a saving of over one half in the cost of labor, made a better flour and produced more than twenty-eight pounds of superfine flour to the bushel.

Various applications of these inventions comprise about all that is used even until now for the movement of grain in the manufacture of flour. The same inventions are also at the basis of all modern systems of conveying.

These inventions were made in 1783, and were so successful that his own mill ran after starting, with practically no attention. He spent thousands of dollars and four or five years of time, but his efforts to have others adopt them were at first entirely unsuccessful. In 1786 he succeeded in securing exclusive rights in the states of Pennsylvania and Maryland. To facilitate the sale of these licenses he wrote his first book, "The Millwright and Miller's Guide." Not many were sold, but a great many were distributed. His agents traveled during the next thirteen years over 100,000 miles, selling these licenses. At first they had small success. The inventions were called "rattle-traps," and one old German is reported saying, "Now dis mus peen sum tamp lazy fellow to mak dem gondrivers."

His was one of the three patents granted the first year of the national patent law, but the patent had expired before any amount of business had been realized. Through

some technicality he was denied a reissue, and millers at once began to adopt it. After a full hearing, in 1808, he received a reissue of his patent, and greatly increased the charge for using. These things involved him in many and costly law-suits, but toward the end the patents were profitable.

When he asked for the exclusive rights to his milling inventions, in 1786, he asked also for protection in building steam road-wagons. Pennsylvania ignored the request as being too visionary for attention. Maryland granted it on the plea of only one man, who said that no one else wanted the right and it could do no possible harm. In the years that followed he diligently sought some one to supply the means. He showed drawings and explained his plans to a number of men, capitalists and scientists, but in vain. Some time during these years he sent an agent to England with drawings of his engine. They were shown to a number of men interested, but failed to secure financial assistance.

In 1801 he decided to build an engine at his own expense, and before it was done it had cost him $3,700 and financially ruined him. It had a six-inch cylinder and eighteen-inch stroke; was set up in public view, and used to grind plaster and saw marble. It was a mechanical success and permanently identified him with the steam-engine industry.

In 1802 he received an order to build an engine to run a boat which was being built at New Orleans. It was built and installed, but the boat was almost at once stranded by floods in an inaccessible place. This ended the project, with a loss of some $15,000. The engine was removed and used to run a saw-mill successfully until the

mill was burnt by incendiaries. Ten years later it was used to run a cotton-press.

In 1803 Evans began business regularly as a builder of steam engines. One of his first orders was from the municipality for a steam-dredger to clean the docks. As his shop was some mile and a half from the river, he decided to mount the scow on wheels and run it as a steam wagon as far as the river. This was done, and for several days it was on exhibition running about one of the public squares. Evans has the honor, therefore, of making the first successful steam-wagon, in 1804. It was a crude affair, with a cylinder of only five inches and nineteen-inch stroke. When afloat he substituted a paddle-wheel at the stern, and at once the boat started off and had no difficulty in passing all other craft on the river. The engine was far too small for the load, and hence the speed was not enough to convince scoffers as to its usefulness, but Evans offered, on a wager of $3,000, to construct a road-wagon that would run on a good, level road against the swiftest horse they could produce. He also tried to make a contract with a turnpike company to construct a steam freight-wagon to run either on the best roadbed or on rails, but both efforts failed to awaken interest.

At this time, about 1805, he began writing his second book, "The Young Engineer's Guide." It was intended to be very complete and "abstruse," but as his engine ventures nearly ruined him for the second time, he abbreviated it and called it "The Abortion of the Young Engineer's Guide." It suggested proportions for a steam engine as follows: Cylinder, twenty inches diameter, five-feet stroke, running under a boiler pressure of 194 to 220 pounds per square inch, and gave certain rules for cut-off. It recommended a cast-iron boiler three feet in diam-

eter, and twenty feet long, with fire at one end, returning through a single internal flue. The Columbian engine was afterward built on these proportions.

In 1807 he established the Mars works for the construction of steam engines, and by 1812 records ten engines in use, and in 1816 speaks of fifty. He wrote also two or three "Addresses" to the people of the United States that reveal the straits to which he was reduced at times. In one of these he says that he destroyed at one time, in sheer discouragement, the drawings and records of eighty inventions.

In 1819 his machine shop and foundry was burned by an incendiary, a boy of twenty. The news of it hastened his death.

It is to be regretted that Oliver Evans failed to receive the financial support that he desired and needed to produce a road-wagon or steamboat according to his ideas; it is to be regretted, because Oliver Evans exhibited in all the work that he did produce, an exceptional mechanical judgment.

He probably would not have produced a perfect locomotive or steam boat but he would have done something creditable and have hastened the coming of the practical. When we remember that he lived at the very beginnings of the use of power machinery, that he was poor and was thwarted at every advance by the selfish conservatism of the capitalists of his day, we can appreciate the obstacles against which he struggled and understand the comparatively small measure of fame that has been his reward.

If he had lived in later times he would have been an engineer of rank. He did enough, however, in introducing the high-pressure steam engine to deserve the credit paid him in the following:

Evans.

"Wherever the steam-mill resounds with the hum of industry, whether grinding flour on his native Schuylkill or cutting logs in Oregon, there do you find a monument to the memory of Oliver Evans."

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Robert Fulton.

1765-1815

Robert Fulton.

▼ ▼ ▼

Robert Fulton was the first American engineer of real ability and training.

He was born in a small inland town of Pennsylvania in 1765 of Irish parentage. His father died when he was young, leaving him with a slight education and the early obligation of self-support. Fortunately he had a passion for mechanics and drawing, so that before he was seventeen he was supporting himself as an artist and draftsman in Philadelphia. By the time he was of age, he was enabled to establish his mother in a home of her own and to go himself to England to study painting with the celebrated West. He remained in England some years, a successful artist, and made many acquaintances and friends among the gentry and nobility who were of great assistance to him in his later undertakings. When he was only nineteen he had taken out an English patent for improving transportation and as early as 1793 there are records of his projects to improve inland navigation. In 1794 came inventions for sawing marble for which he was honored by a British society. About this time also, he invented a machine for spinning flax and making rope. The forerunner of our modern power shovels was his invention also.

In 1796 his plans for a cast-iron aqueduct were ac-

cepted and it was constructed across the river Dee, in Scotland, and at least one bridge built from his designs.

He published a book in 1796, when thirty-one years old, on Improvements in Canal Navigation, that brought him great honor. It was at this time also that he became interested in political economy and sociology and wrote treatises on these subjects that were well received. In fact to the end of his life he consistently looked upon all his mechanical interests in the light of their probable effect on the increase of human happiness. His undertakings were greatly aided by the many beautiful and accurate drawings with which his skill as an artist and draftsman enabled him to freely illustrate his prospectuses and specifications.

About 1797 he went to France to introduce his canal improvements, but finding little interest he turned his attention to other subjects. In 1797 he made his first experiments in the submarine use of explosives. These experiments were carried out with extreme minuteness and precision and gave him a fund of accurate information that enabled him to make an early success of his torpedoes. He was led through these experiments to the subject of submarine navigation in general. He made many fine models but was delayed by the lukewarmness of the French government. At length Bonaparte came into power and in 1801 gave him such assistance as enabled him to carry his experiments to a triumphant success. He had perfect control of his boat in sinking, rising, advancing and turning. He remained under water several hours, traveled a number of miles and returned to his starting point. Then he experimented with bombs and torpedoes from these submarine boats, blew up an old hulk and tried hard to blow up some of the visiting English ships,

but found them too wary for him. This failure dampened the French interests and they ceased to aid him. The English government, however, took him up and, although his experiments were notably successful, they dallied and delayed, evidently content to have withdrawn him from the French. They would have supported him perhaps if he had been willing to give them a monopoly of his inventions and he was willing to do this with the single exception of his own country.

Discouraged in his efforts to obtain aid from England, in 1806 he returned to America and carried on his experiments under the patronage of the United States government. In 1810 Congress appropriated $5,000 for further experiments, but through a misunderstanding the proposed torpedo attack was inconclusive, for a time the government withdrew its aid and Fulton gave his attention to steam navigation in which, all along, he had been interested.

Many minds had been at work on the problem of steam navigation and with some measure of success. There were Papin, Hulls, d'Anxiron, and Henry before the days of Fulton, and Watt, Fitch, Rumsey, Roosevelt and Symington in his own day, who all succeeded in propelling experimental boats by steam. But Fulton was the first who really made a practical and commercial success. Fulton certainly had knowledge of and access to the plans and experiments of some at least of these experimenters, and his success was not so much by new inventions as by more correctly understanding the mechanical problems involved and by designing and proportioning his boat, engines and paddles to meet them.

We have no knowledge of when Fulton first turned his attention to steam navigation, but as early as 1793 he

had made experiments and plans in which he had great confidence. In 1801 Chancellor Livingston met him in Paris, and together they made many calculations and drawings. As we have before intimated, others were at work on the same problem, and Livingston himself had already, in 1798, received a monopoly of the steam navigation in the waters of New York. There were records of experiments at this time by others, but nothing that was conclusive. Fulton at this early date was abreast of all others in his experiments, and he, more than any other, had a fund of exact knowledge of displacement, bouyancy, friction and power required.

In 1803 he experimented in France before the French Institute with a boat 66 feet long, eight feet wide, so successfully that he at once ordered an enlarged engine of Boulton & Watt to be sent to America. In 1803 the monopoly granted to Livingston was transferred to Fulton and Livingston, and extended for twenty years.

As soon as Fulton returned to America, he began to build his boat that was launched in 1807. This boat was called the Clermont and was 133 feet long, 160 tons displacement. Her engine had a 24-inch cylinder, 4 feet stroke and a boiler 20 feet long, 7 feet deep and 8 feet wide. She was successfully launched, and, after correcting a defect in the length of the paddles that Fulton's quick ear had detected, at once made the trip to Albany and returned with perfect success. Soon after she continued to run regular trips to Albany, and always well loaded with passengers. From this time on steam navigation was a commercial success. Mr. Fulton took out from time to time patents on improvements, and in company with Livingston defended their sole right to the steam navigation of New York waters.

Fulton.

Fulton's early interest in canal navigation led him, on his return to America, to become interested in the possibility of connecting the great lakes and the Hudson river by canal. He was appointed a commissioner to investigate the matter in 1811, and his calculuations and suggestions were of value when the canal was finally built.

Returning to Fulton's experiments in explosives and submarine navigation, we find that in 1814 a committee of the citizens of New York were appointed to consider some proposals of Mr. Fulton for defending New York harbor. He exhibited a model war vessel to be propelled by steam, and to carry strong batteries. The committee reported favorably, and the National Congress authorized the President to cause to be built one or more of these floating batteries for the defence of the waters of the United States. A sub-committee was appointed to build the ships, and Robert Fulton was appointed the sole engineer. It was his soul that animated the whole undertaking.

At the same time Fulton presented a model of a submarine boat to the government, by whom it was approved, and he began its construction, but before it was completed Fulton died, February 4, 1815, at the early age of fifty. The building of the submarine boat was abandoned, but the frigate was carried to completion, and successfully launched. July 4, 1815, she made her first trip with full armament to the ocean and back, a distance of fifty-three miles, at the average rate, with and against the tide, of five and a half miles an hour.

As we have seen, the steamboat was only one of the mechanical problems with which Fulton interested himself and mechanical problems were only one of the departments in which his varied powers were employed. He

was an artist of high merit, a civil engineer of ability, a social philosopher of deep insight and warm affection. He was conversant with the French, German and Italian languages and an excellent mathematician.

His fame was honestly earned by habits of careful experimentation, research and calculation. His conclusions were preserved in elaborate notes and beautifully drawn plans.

Personally he was tall and slight, with an attractive face, beautiful eyes, high forehead, and an abundance of dark curly hair. He was modest, friendly, enthusiastic and cheerful—one who easily made and retained many friends. The universal respect for Fulton's greatness showed itself at his death. Legislatures adjourned, state and city governments attended his funeral, and honor rarely, if ever, given to a private citizen, who had never held an office.

John Stevens.

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The story of John Stevens and his sons is very different from that of John Fitch and Oliver Evans. These latter were hampered by poverty and scant education, that limited their usefulness and filled their days with discouragement.

On the contrary, John Stevens and his sons were favored with every advantage that position, wealth and education could give.

John Stevens was born in 1749, in New York, of wealthy parents, and was educated at what is now Columbia College, both as a civil engineer and lawyer.

As a young man he held many important positions. He was a member of the commission authorized to define the boundary between New York and New Jersey. He was a Vice-president of the council of the colony of New Jersey, a member of the first Continental Congress, Treasurer of the State of New Jersey from 1776 to 1779, Colonel in the Continental Army, and President of the New Jersey convention held to ratify the Constitution of the United States.

Mr. Stevens' interest in steam began about 1787, after seeing John Fitch's efforts of that year to propel boats by steam. He was interested in the framing of the national patent law, and was one of the first group to seek a patent. Fitch, Read, Rumsey and Stevens contested for the first

exclusive patents in steam engineering. Stevens' plan was much the same as that of Rumsey, and in a way he joined efforts with the latter to break down the claims of Fitch. Their boiler was a continuous pipe, bent about in a brick furnace, connected at the lower end to a reservoir of water and delivering steam at the other. Read's claim was for a genuine multitubular boiler. They all received patents, with permission to fight it out in the courts.

About 1797 Chancellor Livingstone and Nicholas J. Roosevelt secured provisional protection from the state of New York for exclusive steam navigation. Roosevelt apparently furnished the mechanical ideas, and, in after years, had much to do with the navigation of the Ohio and Mississippi. Stevens and Brunel, the English engineer, and afterward builder of the first Thames tunnel, joined with them to build the first steamboat. It was completed in 1798, but was not able to meet the requirements of the state.

They tried a horizontal centrifugal wheel on a boat of 30 tons drawing, drawing water at the bottom of the boat and discharging it under pressure at the stern.

Soon after, the company was broken up, Livingstone becoming Minister to France, where he met Fulton, and the rights were transferred to them.

In 1804, after several years' experimenting, Stevens built a screw steamer. It was 25 feet long by 4 feet wide, with a five-foot screw, with four blades set at an angle of 35°. The screw was fairly well designed and approximated the design now adopted. The engine was a double direct-acting, non-condensing engine with 4½-inch cylinder and 9-inch stroke. The boiler was of the water tubular type, with 81 tubes made of ⅝ bore gun barrels, about

18 inches long, plugged at one end and protruding horizontally from a central drum.

This was patented in 1803, and two years later in England. The next year he altered this boat to a twin-screw steamer, which seems to be the first of this type made.

The boat was only fairly successful, and not fast enough to secure the coveted exclusive rights, or to be reproduced. Even Stevens had so little faith in the screw as to abandon it in his later boats. Thirty years later, in the evolution of the steamboat, the screw propeller reappeared in much the same type that Stevens favored in 1804, and the credit for its successful introduction passed to Ericsson.

By this time Stevens' second son, Robert L., born in 1787, began to be his active assistant. Together they designed the Phœnix, which was ready for trial within a few weeks of Fulton's success. This boat was a side-wheeler, 50 feet long, 12 feet wide and 7 feet deep. The exclusive right to New York waters having gone to Fulton by priority of success, Robert boldly steered the Phœnix out to sea, weathered a gale and brought her up the Delaware, where she was in use for many years.

Stevens, from this time on, used his very great wealth and influence to break down the Fulton monopoly.

In 1811 they established the first steam ferry from New York to Hoboken to be a part of their stage and express line to Philadelphia.

In 1812 he advocated, before the Erie Canal Commission, a double-track railroad from Albany to Lake Erie to be built instead of the canal. He gave full plans and estimates of cost, and proposed a speed of twenty to thirty miles an hour. His suggestions were reasonable

By the kindness of
Col. E. A. Stevers

and statesmanlike, but were unheeded. In 1830 the South Carolina railroad was successfully built on these same plans.

In 1813 he designed the double-hull ferry-boat, with one internal wheel operated by horse power.

In 1815 he, with his sons, secured the first charter granted in the United States for a railroad. It was designed to run between Raritan and the Delaware as part of their ferry and stage line, but was never built.

In 1823 they secured a charter for a railroad from Philadelphia to Lancaster, which became the first link in the great Pennsylvania Railroad.

In 1824 he secured a patent for railroad construction, and when seventy-seven (in 1826) built the first locomotive that actually pulled a load, on a track, in America. It was only an experiment, but it ran on a circular track of 5-foot gauge and 220-foot circumference, pulling a half dozen people at the rate of twelve miles an hour.

The father, John Stevens, died in 1838. He was a very energetic man, with a keen sense of the commercial value of mechanical improvements. He was an enthusiastic botanist, an excellent classical scholar, a student of philosophy, and a statesman. Having ample means, it is no wonder that his name is connected with so many inventions and improvements.

His eldest son, John C., became a famous yachtsman, the founder of the New York Yacht Club, and an owner of the America that first won the world's championship.

The second son, Robert L., was born in 1787, and became his father's assistant in 1804, and after 1807 took the lead in marine and railroad engineering.

In 1812 he gave much attention to bombs and explo-

sives, inventing a successful elongated percussion shell that was purchased by the United States.

He proposed a circular iron-clad battery for harbor defense, which was to be anchored in the center, and slowly manœuvred by two screw propellers on the outside. It was never built.

In 1815 he built the Philadelphia, which had a speed of eight miles an hour. In 1818 he invented the cam-board cut-off that enabled him to use steam expansively.

In 1821 he designed the now common ferry-boat with over-hanging sides and slips with spring posts. In the years that followed he improved Watt's walking-beam construction, substituting slides for parallel motion to piston rod; invented the split water-wheel, improved on the balanced valve for beam engines, placed boilers on wheel-guards, increased boiler pressure to fifty pounds, used iron trusses for hull construction, and was one of the first to use anthracite coal under boilers.

In 1827 he built the North America, the largest steamboat up to that time. She had a pair of engines 44½ inches diameter, 8-foot stroke and 24 revolutions. She attained a speed of fifteen miles an hour, and used the now common type of return tubular boiler.

In 1830 he became President and engineer of the Camden & Albany Railroad. He decided to abandon the wood stringers with flat iron rails, and invented the now standard T rail, which he designed to spike by hook-headed spikes directly to the sleepers. He went to England to purchase these rails, and succeeded in doing so only after great perseverance in overcoming the natural conservatism and mechanical difficulties. He bought the famous "John Bull" locomotive from the Stephensons. In 1832 he designed the locomotive pilot, and invented

the bogie truck, forms of vestibule cars and methods of wood preservation.

In 1842 Congress authorized him to construct an iron-clad after his designs, making an appropriation for that purpose of $250,000. It was to be 250 feet long, 40 feet wide and 28 feet deep, with 700 horse power. Frequent changes in plans and specifications delayed construction. At the time of his death in 1856 the plans called for a boat 410 feet long, 45 feet wide, 5,000 tons displacement, with twin screw engines. It was to have only two feet free board, with four and one-half inches of iron armor, backed up by five feet of oak. The turret was to be square and immovable, enclosing depressible guns.

Congress alternately favored and rejected the project until Edwin A. determined to complete at their own expense. It is said that the family spent millions on this ship. When Edwin A. died in 1868 he bequeathed the ship and $1,000,000 for its completion to the State of New Jersey. The bequest was accepted, and the work entrusted to General McClellan. The plans were unwisely altered, the money exhausted, and disputes as to the ownership having arisen, the work was abandoned, and for years the boat lay in a grass-grown, improvised dock at Hoboken. In 1881 the boat was broken up and sold for scrap.

The fourth son, Edwin A., inherited his father's commercial ability, and as early as 1820, when only twenty-five years old, was made trustee of his father's estate, which he managed with conspicuous success.

In 1825 the brothers bought the Union Line of stages and ferry from New York to Philadelphia. It was a financial success until merged into the Camden & Amboy Railroad, of which Robert was President and Edwin

Treasurer. The latter managed the finances without passing a dividend for thirty-five years.

He took great interest in the arrangements for railroad management and reports, so that the American system of railroad transportation is in large measure his creation.

He made elaborate experiments as to the resistance of iron armor to cannon shot, and determined on four and one-half inches to resist a sixty-four pound spherical shot.

He devised many useful appliances, the Stevens plow, the closed fire-room for forced draft, but was rather an administrator than an engineer.

At his death in 1868 he bequeathed $650,000 for the foundation of Stevens Institute.

Of the three the father had the characteristics of an inventor—the tenacious fondness for the children of his own brain.

Robert was the practical engineer, taking advantage of everything that came to his attention. His many inventions and improvements all tended toward simplicity and practicality.

Edwin was the best financier of the three, and had his full part in the success of this remarkable family.

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Eli Whitney

1765-1825

Eli Whitney.

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While the American mechanic with all his ingenuity, self reliance and sensible energy, stands out clearly as a type, it would be difficult to designate which one among the many inventors and engineers was the most typical.

Perhaps Eli Whitney comes as near as any. He was born in 1765 in Westboro, Mass. His father and ancestors were of English descent and for the times were counted to be well-to-do farmers. Eli's own early days were spent near the soil, but his mechanical tastes asserted themselves in spite of his inheritance and father's disapproval. As a lad his skill with tools became famous, and he was more and more kept busy with neighborhood repairs, and increasingly to his father's profit. He turned his hand to making and repairing chairs and furniture, violins, canes, nails, and other small articles of wood and of iron. His mechanical curiosity led him to take apart his father's watch, which, fortunately, he was able to put together again correctly. In time he made better tools for himself so that he was able to make excellent steel knives. With the breaking out of the Revolution the price of nails advanced, and, when still in his teens, with his father's permission, he began to make nails as a regular business. This little business grew until he had one or two men working for him. With the close of the war the profit in

nails failed and he turned to making ladies' hat-pins, achieving, by his artistic skill, quite a monopoly.

His early schooling had been quite limited; he seemed to have taken to mathematics rather more easily than to his other studies. At nineteen he set himself to obtaining a college education. His father discouraged the plan, but by dint of teaching school, and his savings from mechanical pursuits, he was able to graduate from Yale in 1792, when twenty-seven years old, having paid his own way through.

To us of these more generous days, it seems rather hard on the boy, after having earned so much and showing such promise, that his father could not have helped him, at least a little.

While teaching school he found time to work with tools, and at college made repairs of the scientific apparatus with such precision and neatness as to astonish his instructors. After graduation he went South to accept a position as private teacher, only to find the position filled and himself stranded. The widow of General Greene, herself a Northerner, but living near Savannah, invited him to make her house his home, and encouraged him to begin at once his law studies. He was able to do her several favors in a mechanical way, and she, in turn, introduced him to prominent visitors to the house. One day the topic of conversation was the depressing condition of agriculture in the South, and the uselessness of raising much "short staple" cotton, because of the difficulty of separating the seed from the fiber. (One negro could separate about a pound a day, although what was done was done in the evening, after the field and house labor was over for the day.)

Mrs. Greene suggested that they give the problem to

Mr. Whitney for solution. At that time he had never seen seed cotton, but a bunch was found, and he gave himself up to inventing a machine to do the work. Mrs. Greene gave him every assistance, and Mr. Miller, the manager of her estates, who afterwards married her, fitted up a room for his accommodation, and should have no small credit for inciting him to persevere in the undertaking.

The design was soon decided upon, but the absence of materials delayed construction. He was obliged to make all his own metal parts; even wire was not to be bought in the State of Georgia. In six or eight months the construction was so far advanced that there was no doubt of its success. It consisted of two parallel cylinders, one made up of concentric rows of sharp hook teeth, and the other of brushes. The teeth drag the cotton through a grid that is not large enough to permit the seed to pass; the cotton is brushed off into one bin and the seed drops back into another. A two-horse power gin run by a rude water-wheel and attended by one man could clean 5,000 pounds in a single day. The cleaned fiber formed only about one-quarter of the gross weight. It thus did the work of from 1,000 to 1,500 men. Mr. Miller and Mr. Whitney formed a partnership for its manufacture. Mr. Whitney, from a characteristic desire to perfect his machine, delayed securing a patent. Of course it was impossible to keep such an event secret, and one night the building was broken into, and the machine carried off. In this way the invention became public property, and before Mr. Whitney could secure a patent there were a number of machines built, and in operation. Mr. Whitney immediately returned to Connecticut. He made every effort to perfect the machine, secure a patent, and manufacture in sufficient quantities to meet the demand. The invention

was made in 1792-3. The year 1794 was spent in securing the patent and beginning the manufacture. Suddenly, in the spring of 1795, his shop, with all his machines and papers, was destroyed by fire, leaving him penniless, with a debt of $4,000 at high rates of interest.

It was their intention at first to engage in ginning cotton themselves and maintain a monopoly of the business; but their delay in getting machines at work, their hesitancy, and later on their inability to supply machines, almost forced others into the business, so that when he began to defend his patent rights he met not only the resistance of infringing makers, but the opposition of planters also, whose gratitude naturally went to the ones who had most promptly supplied the machines, and at lowest rates. Steadily but surely, and carefully as ever, Whitney began again the manufacture of gins, but it was not for several years that he could supply any quantity, and finally he apparently gave up the manufacture entirely.

By 1795 he began lawsuits to defend his rights, but it was not until 1797 that the issue of the first suit was announced, and, after all his exertions, it was unfavorable. From this time on, the vexatious lawsuits, often a score at a time, dragged along. Judges would often charge in his favor, while juries would decide against him. He found it well nigh impossible to collect royalties, much less to sell machines, in the face of general infringement. In 1801 Whitney sold a general right to use the patent to the State of South Carolina, and the next year North Carolina began to reimburse him by a tax on each gin. Tennessee also made a contract, which it afterward repudiated, however. But Georgia persisted in denying him any return. In 1807 a most important decision was given in his favor. It was of little avail, however, because the life

of his patent had nearly expired and it had taken nearly all he had received from one direction to cover the expenses of litigation in another. In the course of these thirteen years of lawsuits, Mr. Whitney made six journeys by chaise to the South. His partner died in 1803, and from henceforth he defended his rights alone with remarkable patience and ability. In 1812 he made application to Congress for a renewal of his patent. He made a powerful plea, showing the immense value of the invention to the nation, the large fortunes that had come to individual planters, and contrasted the meager returns to himself, which had been swallowed up in defending his patent. In the face of this cogent plea, Congress refused to renew the patent. When we consider what his invention had accomplished, it seems almost incomprehensible that Congress should have refused the request.

It had revolutionized the cleaning of cotton, one gin doing the work of a thousand men. It had revolutionized the agriculture of the South, and later of Egypt and India, by giving them in short, staple cotton, a crop that in a few years trebled the value of their land, paid off their debts, and gave employment to men, women and children. It increased the cotton crop in the United States from 2,000,000 pounds (mostly "long staple") in 1791 to more than a billion pounds fifty years later. . The exports increased from 138,000 pounds in 1792 to 860,000,000 pounds fifty years later. It made "Cotton King" for nearly a century, at one time constituting seven-tenths of the national exports. It at once rendered valuable millions of acres of land along the Gulf, and quickly setled and added four immense states to the Federal Union. It changed the clothing of the world from wool and flax to cotton, and with Arkwright's spinning jetty, made Eng-

land the foremost manufacturing nation of the world.

For this inestimable gift, Whitney netted almost nothing. In his petition to Congress he said that his entire receipts up to 1812 had not been equal "to the value of the labor saved in one hour by the machines then in use in the United States." Whitney became convinced, as early as 1798, that the gin might never be a source of income to him, and therefore began to look about for something else.

His invention and many litigations had brought him into wide acquaintance with national officials and affairs. At that time Congress was considering the manufacture, in this country, of her arms, and Mr. Whitney proposed to undertake the work. He was given an order for 10,000 muskets, 4,000 to be delivered in one year, and the balance in two years. Mr. Whitney went at the undertaking in his usual thorough and systematic way. He developed a water-power, erected suitable and adequate buildings, considered ways and means for a larger and better product, designed machinery to effect it, and trained workmen to skill in the new employment. The contract was signed in January, 1798, but the difficulties were greater than anticipated, and delayed the fulfillment of the contract. It was eight years, instead of two, before it was completed, but the progress of the enterprise, and the character of the product as delivered, was so satisfactory otherwise, that Congress treated him with the greatest consideration. His shops at New Haven became the Mecca of government officials, manufacturers, traveling notables, and foreigners, and that which he could show was well worth a journey, for his innovations in the manufacture of arms were as epochal as his invention of the cotton gin. Hitherto all such things, and machinery in general, had been made one by one, as it were or at best the main parts were

made one by one. Skilled workmen would make entirely a single machine, or object or part; so that while the finished products were similar, they were not exactly alike or interchangeable. Moreover it took a high degree of skill to effect a satisfactory result, and the production was therefore limited. The manufactures of the world were on this basis. All firearms used in America at that time were imported from England and made after that method.

At the time this contract was awarded to Whitney, similar contracts were given to others, and all failed to fulfill the contract. Had Whitney followed this English, and usual method, he would doubtless have failed also, but his admirable judgment led him to make an entirely new departure. His plan was to make the parts of the muskets as far as possible by machinery, and so exactly duplicates of each other as to be interchangeable. To accomplish this result he planned to carry each separate part through its successive operations in lots of hundreds and thousands.

Professor Olmstead, in speaking of him, in 1832, says: "His genius impressed itself on every part of the manufactory, extending even to the most common tools, all of which received some peculiar modification, which improved them in accuracy, or efficacy, or beauty. His machinery for making the several parts of a musket was made to operate with the greatest possible degree of uniformity and precision. The object at which he aimed, and which he fully accomplished, was to make the same part of different guns, as the locks, for example, as much like each other as the successive impressions of a copper-plate engraving."

A visit to the old shops and to the grandson of Mr. Whitney, failed to discover any details as to the machines

with which he accomplished the results. All seem to have disappeared with the lapse of years and business changes. Hand milling machines with hard brass bearings were at least part of the outfit. It is to be regretted that no record even remains of what these machines were.

As early as 1822 Mr. Calhoun, then Secretary of War, admitted that Mr. Whitney's improvements were saving the government at her two arsenals, $25,000 per annum.

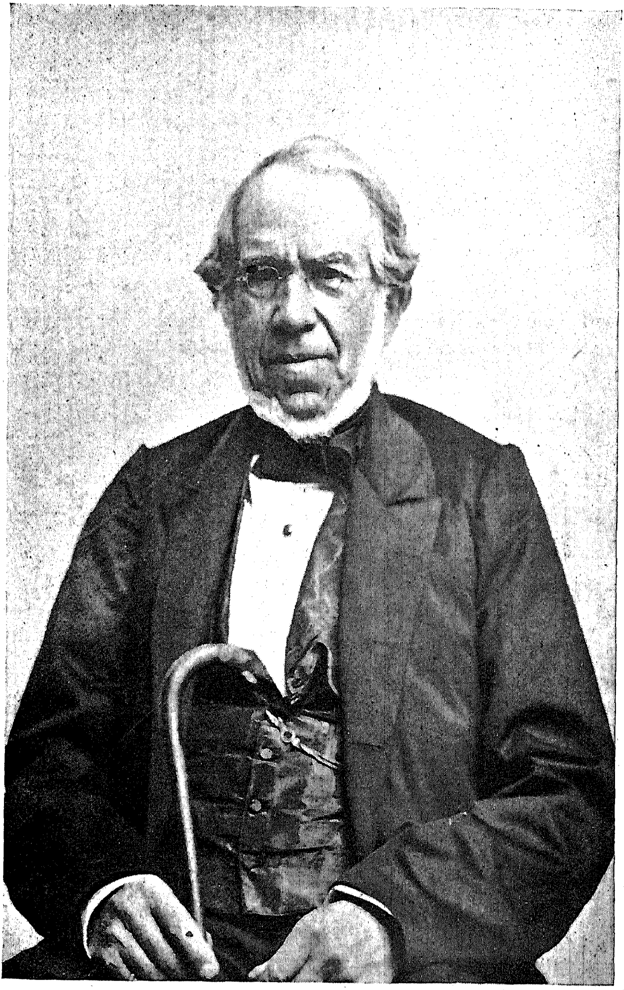
The value of Mr. Whitney's services in the introduction of the system of interchangeable parts, is appreciated the more when we recall that English muskets were being made by the old hand method as late as the Crimean War in 1858. At that time, being utterly unable to get an adequate supply of arms by the old method, she asked Sir Joseph Whitworth, to fit out her arsenals with his special machine tools.

Whitney's system not only revolutionized the manufacture of muskets, but was the basis of American superiority in all manufactures. It made possible the production of any and all machinery in enormous quantities, with the greatest speed and the highest precision. Think of muskets, revolvers, knives, shoes, gloves, screws, watches, knitting machines, sewing machines, typewriters, bicycles, agricultural machinery, and the multitudinous list of modern necessities that are absolutely dependent for their economical production upon this system inaugurated by Mr. Whitney! Think of these things and pay tribute to his genius.

Eli Whitney was a gentleman. He was large of stature, with an attractive presence and genial, winning ways. His splendid mind, developed by the best education of the day, and varied experience, mellowed by a generous, lov-

able disposition, made him calm, dignified and strong. Patience, steadiness, persistence were also striking characteristics. As a mechanic he was remarkably skillful and precise, with great resources and sound judgment. He was a man of business rather than an engineer. His arrangements, even of common things, were marked by singular good taste and a prevailing principle of order. His mind was remarkably well disciplined. He could command it to such a degree that there was no confused or incomplete thinking. Even after long interruptions he could resume consideration at the point where he left off, with no hesitancy or necessity for reconsideration of ground already gone over. He was perfectly able to resist the subtile temptation that besets inventive minds, to fritter away one's mental strength on a thousand and one attractive suggestions. He could hold his acute mind closely to the thing in hand, and that which his judgment said was best worth thinking about. He was far from being narrow-minded, but was deeply interested in the larger questions of government, literature, science, art and religion, delighting in nothing more than friendly converse with cultivated minds.

Socially he had many and intimate friends. He corresponded with some of his schoolmates throughout life, and children were invariably drawn to him by his caressing ways. He had a personal acquaintance with every President to the time of his death, with most of the leading statesmen, scholars and business men of his day. But to none did he reveal his best gifts more freely and happily than to his own family and workmen. He died in 1825 after a long and severe illness, but in his deepest suffering he never failed in serenity and kindly consideration for others, the marks of a true gentleman.



Thomas Blanchard

1788-1864

From photograph owned by
F. S. Blanchard, Worcester, Mass.

Thomas Blanchard.

▼ ▼ ▼

Thomas Blanchard started out in life under very discouraging circumstances. His father was a New England farmer, of Huguenot descent, who added to his income by doing blacksmith work for his neighbors.

Thomas was born in 1788, at Sutton, Mass., the fifth of six sons. As a boy he was far from promising, stuttering badly, and counted by some to be half foolish. He took little interest in farming or study, and spent his time whittling shingles, making windmills and miniature water wheels. As he grew older he became interested in iron work, and as his father refused him the use of his forge, he saved up all the charcoal he could gather and hid it behind a wall. Then he built a rude forge and used an old wedge driven into a log for an anvil, waited until his parents were absent and tried his hand at working iron.

At thirteen he heard of an apple-paring machine, and after patient experimenting and repeated trials succeeded in making a machine that would pare more apples than a dozen girls at the winter "bees."

This success deepened his inventive interest and made him of less use on the farm, so when eighteen his father sent him to work for an elder brother who made tacks in the neighboring town of West Millbury. Here he was put at the monotonous task of heading the tacks by hand. The points were first cut from strips, and then had to be

picked up by the thumb and finger, gripped in a vise, and headed by a blow. He was given a certain number to be made each day. One of the first things he made here was a counting machine that would ring a bell when the required number was complete. His brother forbade him spending any time in these idle projects, but his inventive genius could not be suppressed. He began to consider a machine to cut and head the tacks at one operation. The idea came to him long before he had the skill or means to construct. For six long years he worked at the idea; expending everything he could earn to buy materials, throwing away the old as new improvements suggested themselves, carrying the models about with him from place to place, persisting in spite of every discouragement. He became so poor that his own brother refused to trust him for groceries, even when his family was actually suffering.

At last it was a success; it made much better tacks than could be made by hand, at the rate of five hundred a minute. It was sold for $5,000, which placed Blanchard in comfortable circumstances. The tacks were all sold, for some years at least to one house, who kept the source of supply secret and realized handsomely on the sales.

At this time the attempt was being made by the Government to manufacture its muskets in this country; one of the shops making the attempt was located at Millbury. The barrels had been made by hand, but the process had been so far improved that the straight part of the barrel was then being turned in a lathe. There was an irregular enlargement at the butt where it was joined to the stock that still had to be finished by hand at considerable expense. Blanchard's inventive powers becoming recognized, he was sent for and asked if he could get up a machine that would do this. He looked the machine over

carefully and then, beginning a low monotonous whistle at the same time swinging one foot, he relapsed into deep thought. It was not long before he suggested the addition of a certain cam motion to the lathe that would permit turning the cylindrical part and the oval end at the same operation.

The knowledge of this coming to the attention of the Government, he was sent for to introduce it at the Springfield Armory. While the workmen were gathered around to witness its operations, one said to another, "Well, John, he has spoiled your job." Still another exclaimed that "he could not spoil his, for he could not turn a gun stock." Blanchard overhearing the remark answered "I am not so sure of that, but I will think of it a while." On his way home soon after, the whole principle for turning irregular forms came to him. In a short time Blanchard had built a wooden model of his idea, and, sure enough, it turned a miniature gun stock with perfect accuracy.

The principle is this: A pattern and block to be turned are fitted on a common shaft, that is so hung in a frame that it is adapted to vibrate toward or away from a second shaft that carries a guide wheel opposite and pressing against the pattern, and a revolving cutter wheel of the same diameter opposite the block to be turned. During the revolution of the pattern the block is brought near to or away from the cutting wheel, reproducing exactly the form of the pattern.

The beauty of the invention is that by varying the relative sizes of the guide wheel and cutting wheel, any variation in size relative to the model can be secured, and by reversing the transverse motion of the cutting wheel, a perfect right and left can be made from the same pattern. Then by varying the transverse speed of the cut-

ting wheel in relation to the guide wheel, the object is made either longer or shorter than the model.

Blanchard immediately secured a patent and was paid by the Government to set one up at the Harper's Ferry Armory, and later at the Springfield Armory. The introduction of this machine opened up the way to others. Blanchard was placed in charge of stocking muskets at the Springfield Armory, and during the next five years introduced no less than thirteen machines for the better manufacture of muskets. The most important of these was a machine for making the irregular recesses in the stock for the barrel, lock, etc. The idea for this machine came to him, it is said, from watching the labors of a wood-boring insect.

One of the common applications of this invention is the well-known die sinking machine and upright milling machine. The fame of these inventions spread to England and two committees of the British Parliament came to America for the sole purpose of investigating these reported inventions. The second committee left an order for $40,000 worth of Blanchard machinery.

While Eli Whitney began the system of interchangeable parts in the manufacture of muskets, it was these dozen or more machines of Blanchard's that made it possible to carry out the system in its completeness.

Being thus occupied in Government work, opportunity was open to infringers of the patent to apply it in other ways. During the first term of the patent no less than fifty machines were put in operation for various purposes, turning shoe lasts, wheel spokes, tackle blocks and hat forms, from which he derived no benefit. The patent was originally granted in 1820, and was twice renewed, a very unusual proceeding.

One of the elder Choate's clever sayings is preserved with the granting of this second extension. Blanchard was in doubt as to his success and to help his case along set up his lathe in the Capitol at Washington and began to turn marble busts of Webster, Clay and others from plaster casts. After he won his case—Choate in reporting to his clients said, "Oh, Blanchard, same down here and 'turned the heads' of the members so nicely that he won his case."

In the early history of this invention the question of reality of invention was contested by one of his neighbors. A hearing was granted, to be held on the village green. The neighbor, who was a brass worker by trade, presented a beautifully made model in brass, while Blanchard's model was a crude wooden affair, but the evidence was altogether in his favor, and little was heard afterward of this contestant for the honor of inventing the lathe for irregular forms.

Blanchard had many troubles in defending his patent, and even to the end realized but a comparatively small amount directly from the invention.

By this time Blanchard came to considerable repute as a mechanical expert, and was frequently employed henceforth in lawsuits and investigations in that capacity.

In 1825 Blanchard became much interested in the subject of steam road wagons. While still at the Springfield Armory he made a working model that was very successful and for which he received a patent. He had ideas also about rails and turnouts, but his efforts to organize a company or secure capital, first in Boston and later in New York, having failed, he apparently abandoned the idea.

Blanchard.

In 1826 an effort was made to improve the navigation of the Connecticut river. At first steamboats were tried, but the rapids were so great that it was a failure. Then a canal was built around the worst rapids, and Blanchard was asked to design a steamboat, which he did, but it was also unsuccessful. This failure deepened his interest, and he made an elaborate study of the whole question, the result of which was an important improvement. The improvement consisted in locating the paddle wheel at a particular distance beyond the stern, where the water set in with the greatest velocity. Hitherto the wheel had been located close up to the stern or at the sides. By Blanchard's discovery the maximum resistance to the paddles was secured, and a steamboat could be driven up rivers whose rapids had hitherto prevented steam navigation. He also built boats with two engines driving the wheel shaft by cranks set at 180 degrees on the ends, which secured the more constant power needed to ascend strong rapids. The result of his efforts was to move the head of navigation from Hartford to Springfield, and double the travel and transportation between the two places. He even navigated the rapids 150 miles beyond Springfield.

Proving that small rivers could be successfully navigated by steamboats, brought Mr. Blanchard many applications for assistance. By 1830 he had boats running on the Allegheny and other tributaries of the Ohio, and so established his method of construction that it came into general use.

Another of his inventions was the process of steaming wood for bending. Hitherto when bent sticks were required for ship construction and other purposes, the woods were searched for satisfactory timbers. Mr. Blanchard made more money by far from this invention than any

other. The U. S. Government paid him $50,000 for the right to use it in ship construction alone. He received the first year from a manufacturer of school slates over $2,000 in royalties. It was immediately used in carriage work for wheel rims, and thills, for bent furniture and endless other purposes.

He also made inventions in woolen machinery and other purposes, the details of which have been forgotten. In all he secured twenty-four patents.

Although he started in life under such unfavorable conditions, he won out in the end. He overcame his stuttering, improved his personal appearance, made up by observation and experience for his lack of education, and by his inventions changed his early poverty for comparative wealth. He was able before he died to fulfill an assertion made to the villagers of West Millbury, when in extreme poverty and youthful awkwardness he was railed against for his shiftlessness, that he would yet "drive up through here in a coach and four."

He died in 1864, leaving a widow, whom he had married only ten months before. She still survives him, bringing closely home to us the recentness of the origin of things mechanical that now seem as though they always had been.

▼ ▼ ▼

Elias Howe

Portrait through kindness of
W. S. Heffernan, Spencer, Mass.

Elias Howe.

▼ ▼ ▼

Unlike many of the great inventors, Elias Howe is identified with only one invention, the sewing machine.

He was born in Spencer, Mass., 1819. His father was a farmer, who had a small mill for grinding grain. The inventive faculty seems to have run in the blood, for one uncle, William, designed the first truss bridge erected in this country, the well-known Howe Truss over the Connecticut at Springfield; and another uncle, Tyler Howe, invented the spring bed.

He was a younger son of a large family, and was set at work at light tasks when only six years old, setting the wire teeth in cotton cards; then he helped his father in the mill until eleven. His only schooling was received during the summer term for a very few years. At eleven he was bound out to a neighboring farmer, but being of slight physique, and not at all strong, was soon released and returned to work with his father until sixteen. He seems to have preferred mill work to farming.

Then he left his home to work as a machinist in Lowell, Cambridge and Boston. At twenty-one he was counted a good machinist, but rather inclined to suggest different ways of doing things than of following instructions. With this disposition and his poor health he received small pay and irregular employment. He was already married, and even with the coming of children,

his wife found it necessary to take in sewing to eke out the family income.

At one time, when working for Ari Davis in Boston, he overheard a conversation between his employer and an inventor of an unsuccessful knitting machine. Mr. Davis advised him to drop it, and invent a machine to do plain sewing. Howe overheard the remark and remembered it. One day when at home, sick and discouraged, he watched his wife sewing, far into the night, and the determination to invent a sewing machine took complete possession of him. He was well fitted for the task. He was a good machinist, and had been constantly employed on new spinning and weaving machines.

At first he worked evenings, and at intervals when out of work, but finally gave up regular work altogether. Meanwhile his father had moved to Cambridge, and started a shop for slitting palm leaf for hats. Elias went to live with him. He set up a lathe in the attic, and continued his efforts. He first tried a double ended needle, with an eye in the centre, and worked on it for a whole year before becoming convinced that it would never work. then he tried one device after another until the summer of 1844, when the idea came to him of making the eye at the point of a grooved needle, and locking the stitch by another thread carried by a shuttle.

It is said that the idea came to him in a dream. He dreamed that he was before a king who ordered him to perfect his sewing machine at once, or forfeit his head. He dreamed that he tried and tried and failed, and that the savage warriors advanced to lead him to execution. Then he noticed that they were armed with spears, and that the spears had holes near their heads. This was the foundation idea of the modern sewing machine.

His first model was completed in October, 1844, and although made of wood and wire, and crude to an extreme, would actually sew. In this model he used a curved needle vibrating on an arc, with the cloth to be sewn held vertically, and carried along by points on the side of a disk, that revolved slowly toward the needle. Its capacity was three hundred stitches a minute.

While Howe had great faith in his invention he was in dire poverty. He only left his invention to do odd jobs when absolutely obliged to provide food for his family. To make matters worse, his father's shop burnt down, closing his source of aid. He thought he needed $500 to construct a machine. Finally an old schoolmate, named Fisher, a coal and wood dealer, agreed to board him and his family, furnish a workroom, and advance $500. Consequently Howe moved into Fisher's house, and during the winter of 1844-5, the sewing machine was constructed.

It was not until late in 1845 that Howe secured his patent. Meanwhile he did his best to awaken interest in the machine. Everyone praised it, but no one would invest a dollar. He had it on exhibition in a Boston clothing factory for two weeks. He offered to sew any seams that were brought to him and did so in one-seventh the ordinary time of doing the same work by hand. He offered to sew five seams in less time than five other seams of equal character could be sewn by the fastest sewers that could be produced and won in the trial that followed. The judge in his sworn statement said that Howe's work was the neatest and strongest.

But fear of the journeymen's enmity and the high cost kept all the tailors from buying. Completely discouraged, Fisher withdrew from the partnership, but Howe kept doggedly at it. Forced by sheer hunger, he gave it up for

a short time to be a locomotive engineer. His health failed him at this, and for want of anything else to do, he again sought to sell the sewing machine. Unsuccessful in this country, he sent his brother to England to try and sell it. William Thomas, a corset and umbrella maker, bought the machine and right to use it in his business for $1,250. He also hired Elias to come over and work for him for $15 a week.

There was also a verbal agreement that Thomas was to obtain an English patent and give Howe $15 for every machine built and sold in England outside of his business. This royalty was never after acknowledged or paid. It is said Thomas made over $1,000,000 from the ownership of this English patent.

Elias went over, and for a few weeks worked for Thomas. Then he was dropped, and tried to find other work; then made one or two sewing machines, which increasing poverty forced him to pawn. Then he pawned his patent papers, and worked his way back to America as a cook on an emigrant steamer. Arriving in New York, he learned that his wife was dying, but was unable to go to her, until his father sent him a few dollars. He hastened to her, and was with her a few hours before her death. She who had cheerfully and loyally suffered with him, was denied a share in the wealth that soon was to be his. Following closely on this great sorrow, the news came of the loss at sea of all his household goods, leaving him absolutely penniless and in debt.

This was the proverbial darkest hour before the dawn. During his absence in England, imitations of his sewing machine had been sold to great advantage, and the possibilities of the invention began to be appreciated. Howe's patent proved to be well drawn, and in the suits that fol-

lowed left no shadow of doubt as to his rights. Royalties began to flow in, and after the crucial suit against Singer was decided in 1854, the money value of the invention became fully apparent. In 1863, his royalties were $4,000 a day, and totaled, it is said, above $2,000,000.

Judicial decisions affirmed again and again that, "no successful sewing machine has ever been made.......... which does not contain some of the essential devices of this first attempt."

Another authority said that every adult since the day of its invention is indebted $200 for the savings due directly to the sewing machine.

Elias Howe was a fine looking man, with a large head and flowing hair. His bitter struggle with poverty through so many years left him reserved, quiet and charitable. During the Civil War, such was his patriotism that, although very wealthy, he enlisted as a private soldier in a Connecticut regiment, and went to the front. Then in the dark days that followed, he accepted the lot of a common soldier without complaint. When the Government funds ran low, and there was no money with which to pay them, he went without as they went without.

One day a ragged soldier appeared at brigade headquarters, and asked to see the pay-master. He waited his turn, and then asked if it was known when the 17th Connecticut would receive their pay. He was answered rather brusquely that when the Government sent the money they would get their pay, and not before. He asked how much was due them, and wrote a draft for the amount, some $31,000, and received a Government receipt.. In a few days he received his $28.60 in back pay just the same as the others.

In 1867 he received the cross of the Legion of Honor

from France. The same year this kind hearted and benevolent man took a severe cold, from which he died when only forty-eight years of age.

▼ ▼ ▼

J. Ericsson

1865

John Ericsson.

▼ ▼ ▼

John Ericsson was a great engineer. He was born in Vermland, West Central Sweden, in 1803, where his father was an inspector of mines. His father's people were miners who had come to be owners and operators of small mines. His father was a man of refinement, well educated and a good mathematician. His maternal ancestors were of Flemish and Scotch blood, who came into the country as military officers under Gustavus Adolphus. His relatives, therefore, included families of rank and wealth. His mother was a woman of unusual presence and ability. She was tall, beautiful, intellectual and of great firmness of character. To her was John indebted doubtless for his strongest characteristics.

John had one, an older brother, Nils, who was also of exceptional ability, and as director of imperial railroads was later made Baron Ericsson.

John was precocious and very early showed the bent of his later years, by insisting on making his letters after his own fashion and spending hours in sketching the machinery of the mines, when other children were at play.

1811-1814 were trying times for Sweden and many were ruined in business, among them this family of Ericsson. They suffered severely for a time but after the father had secured work on the newly begun Göta Canal the fortunes of the family improved.

When the father went to work on the Göta Canal, John was eight years old, and it was at this early age, in the offices of the company, that he first learned to draw to scale and make maps. By the time he was ten years old he could make accurate drawings. His father secured instruction for him in architectural drawing from Pohl, who was renowned in his day, from Lieut. Bradenburg, who was the most accomplished draftsman in the Mechanical Corps of the Swedish Navy, from Pentz, a German military engineer, and others.

The lad's drawings were brought to the attention of Count Platen, the chief of the Mechanical Corps of the Navy, who was so impressed that the boys were made naval cadets and later, when only 12 and 14, were detailed as "canal pupils" to the drawing office of the canal and John was set to work making the finished drawings for the archives. When thirteen he was made assistant leveler, and at fourteen full and only leveler at one of the stations and responsible for all the local calculations and records. The ability to fill such a position shows unusual natural ability and training. At seventeen he entered the Swedish Army. As a soldier he continued his studies of land surveying and took great interest in the mathematics of artillery.

He was employed in drawing the maps for a military survey of Jemtland which were paid for by the number produced. He won a prize for the excellence of his work and was so indefatigable that for a time he was carried on the pay roll as two persons, so as not to awaken suspicion of favoritism. Also in experimentss that resulted in the construction of a flame engine. With this his love for a military life waned and, although now a Lieutenant at twenty-two, secured a leave of absence and went to

England in 1826. The Crown Prince, his friend, secured for him a commission as Captain, which he accepted and at once resigned, but to the end of his life cherished this one title, Captain in the Swedish Army.

His flame engine did not prove successful and so he settled down to work in England. He became junior partner in a firm of machine builders, under the firm name of Braithwaite & Ericsson. In this connection he rapidly developed as a mechanical engineer. There followed from his pencil a combined gas and steam engine, a marine hot air engine, a pumping engine, and air compressor.

He used this latter in 1828 to transmit power, the first use of compressed air for this purpose. In 1829 he patented a mechanical draught for marine boilers, a surface condenser, and also devised the plan of placing boilers and engines below the water line.

This same year brought forth also his steam fire engine, the one now in universal use.

This connection with Braithwaite put Ericsson at the beginnings of locomotive construction, and his "Novelty" was the only one that really competed with Stevenson's "Rocket" at the Rainhill trial.

Both used steam blast, but the Novelty had also a mechanical draught, better springs, horizontal connection to cranks, was lighter and far speedier, going at the rate of nearly one mile a minute and 32 miles an hour.

It was an experimental engine and built altogether too light for the service. After several delays owing to breakage and defects due to construction rather than to the principles involved, Ericsson withdrew the engine before it had covered the required distance. It was characteristic of Ericsson to do this without consulting his partner. In spite of these accidents and withdrawal many

Your most obdt. Servt
J. Ericsson

at the time thought it to be a better engine than Stephenson's Rocket. With this Ericsson appears to have dropped locomotive construction.

In the years that followed inventions came from his prolific brain at the rate of three and four a year. A successful steam turbine, that he would have done well to have developed, a rotary engine, a process for making salt.

In 1832 came the original use of an independent power blower for marine boilers and a new rotary engine.

Many of these inventions that had to do with steam were not very successful, but served to spur Ericsson on to get, if possible, a substitute, so he gave more and more attention to his original invention of the heat engine.

In 1833 he patented a caloric engine that had a regenerator in connection with it and for years he continued to try and make it a success, but was as continuously baffled, because he, like everyone else at that time, considered heat to be a substance instead of a form of motion. He found that the heat from a handful of fuel could not be used indefinitely, although it was not until fourteen years later that the true theory of heat was understood and the error of these gropings in the dark discovered.

Ericsson's early caloric engine was constructed all right, but the expectation of its efficiency was exaggerated. Other inventions were a sounding instrument, a motor for canal boats, a hydrostatic weighing machine, a machine for cutting files and a semi-rotary engine.

Just previous to 1833 he began experiments designed to do away with the paddle wheels of steamers, that resulted in 1835 in the invention of the screw propeller. In 1837 he built an engine coupled directly to the propeller shaft. This was a success from the start and although

slow to be accepted in the years that immediately followed, in time steadily won its way to almost universal use.

John Ericsson married in 1836 an attractive young lady of good family, but domestic duties hung heavy on his shoulders. He had no quarrel with her and always provided liberally for her support, but his heart was with his inventions—not at home. Although she afterwards came to him at New York, she did not remain long, but soon returned to England where she died years later without ever seeing him again.

In spite of his many inventions, perhaps because of their number, the firm of Braithwaite & Ericsson failed in 1837 and for a short time Ericsson was in the poor debtors' prison.

Before this Ericsson had become acquainted with a wealthy U. S. Consul named Ogden and a U. S. Naval officer named Stockton. With their assistance an iron steamer of 70 ft. length and 50 h. p. was built, and although strikingly successful, awakened no particular interest. These men appreciated Ericsson and encouraged him to go to America to seek the recognition that the British admiralty were too conservative to give.

With this small steamer Ericsson crossed to America in 1839 and at once found interest and work. He won a prize for his steam fire engine, received orders for his propeller and engine on lake vessels and later, on coastwise steamers. He built also one of the first compound marine engines. At that time also began the intimate relations that existed for a half century between Ericsson and Delameter, the New York engine builder.

In 1841 Capt. Stockton secured an order from the U. S. Government for a 600 ton screw steamer, to be known as the "Princeton." As far as the government were con-

cerned they had dealings with Stockton only, but the latter came privately to Ericsson for each drawing as it was needed and asked him to include any and all new ideas of value, which he did. The only contract he had was private letters from Stockton, saying that he would be paid, in time, not only for his services, but also for the use of his patents. Among the novel features introduced by Ericsson were the screw propeller, double, direct acting, semi-cylindrical engines placed below the water line, a 12-inch wrought iron, hooped gun with self-acting lock and friction recoil gear, telescopic funnel, mechanical draught and many other original devices.

The steamer was an unqualified success, but Stockton in making his report forgot altogether to credit Ericsson for his part and, when the latter put in a bill for two years' services and expenses, refused to endorse it. The claim was again and again allowed by the Government, but was never paid, nor was anything ever given him for the use of his patents.

To add to the unpleasantness Stockton had added another twelve-inch gun of his own design that burst while on exhibition before a large and official company. Many were killed and injured and the success of the steamer as a whole was clouded for some time.

Stockton had omitted to credit Ericsson for his cooperation in the design and construction of the steamer but did not hesitate to blame him publicly for this disaster. The real facts were soon known, however, and Ericsson has always received the credit and honor for the Princeton's construction, if not the pay for it.

By 1843 there were fifty steamers fitted out with screw propellers. The same year he built a twin screw

steamer and little by little the propeller was adopted by all maritime nations.

Some of his minor inventions at that time were instruments to measure distances at sea, hydrostatic gauge, fluid meter, alarm barometer, pyrometer, rotary fluid meter and sea lead.

He still continued his studies as to the nature and application of heat as a mechanical force. He built eight caloric engines between 1840 and 1850 and the ninth in 1851 was counted a success. A ship of 2000 tons with caloric engines having four cylinders each of 168 and 137 inches diameter, was built and successfully tried in nine months and a half from the laying of the keel, a remarkable illustration of the correctness of Ericsson's designs and of his industry and energy. "Up to that time (1853) no stronger or finer ship had been built in the United States" than this, the "Ericsson." But it was at the same time a mechanical triumph and a commercial failure. The principle has never again been used for large units, but increasingly for small purposes, where economy, simplicity and safety are of more account than space and first cost. For this invention Ericsson received later on the rarely given Rumford medal. The next year, 1854, Ericsson designed and sent to the Emperor of the French complete plans for a turret warship.

This was the training that Ericsson received for forty years previous to the outbreak of the Civil War, continually grappling with the mechanical problems of artillery, war ships and motive power. Although an officer of the Swedish Army and intimately connected with marine construction for war purposes for thirty years, he was still looked upon by government officers as a civilian and, when he offered his services to President Lincoln for the crea-

tion of an adequate navy, he was disparaged. Nevertheless, when the real pinch came and the improvised Southern gunboat Merrimac was almost ready to sweep the antiquated wooden gun ships from her way to the unprotected harbors of the rich North, it was Ericsson and he alone who was ready and able to design and construct a new engine of war capable of meeting and overcoming this new peril. So skeptical were the officials of his ability to do this that his offer was at first declined. He was too proud to beg for the privilege, but at last his friends deceived him into believing that it had been decided to give him the contract, but that it was necessary first for him to go to Washington and explain his plans in detail. So he went, and learned after entering the room the real facts. After earnest persuasion he consented to explain his plans, which he did so effectively that in four hours he was given the order and in five short months the Monitor was turned over to the Government. It was ordered September 14, keel laid October 25, steam applied December 30, launched January 30, delivered to the Government February 19, 1862. Ericsson designed everything and everything was constructed under his eye—hull, turret, steam machinery, anchor hoist, gun carriage, everything. In a hundred days from the laying of the keel the engines were put in motion under steam. Ericsson's work during this time was herculean; the slightest mistake, break, delay, would be ruinous. He had done what he promised—provided an impregnable battery, armed with the heaviest gun known, hull shot-proof from stem to stern, rudder, propeller and anchor protected, and of light draught.

The battle was fought March 9, 1862, and so decisive was the result that it marked the passing of wooden ships

of war and the coming of heavily armed and armored, revolving turret, battle steamers.

Although universal honor flowed in upon Ericsson, both from home and abroad, the transition was not easily made, but little by little it was made and fame and fortune were the rewards of his genius. Bear in mind this transition was not from one style of ship to another, but was a passing from the sailor to the engineer, from hand-to-hand fighting subject to uncertain wind and tide, to nice calculations of mass efficiency, flight of projectiles, armor versus cannon, and the sure effectiveness of steam and electricity. In all this Ericsson was the pioneer.

During and immediately following the war he brought forth improvements continuously, not only in turret armor-clads but in repeating rifles, flying artillery, friction recoil gear, torpedoes and engines.

These were not isolated inventions, but were practical improvements that were made in the course of the design and construction by him of scores of important armor-clads for different European and American governments. As late as 1887 he was still in communication with the United States Navy Department, this time as to the value of the type of vessels favored by Secretary Whitney's administration.

In steam engineering he held to the last for two cylinders, bringing their combined power to bear on a common crank shaft and at right angles to each other. He believed in using the expansibility of steam, but disbelieved in a multiplicity of cylinders.

Toward the latter end of his long life he gave much thought to the heat energy of the sun and methods for utilizing it. This brought him into controversy with the foremost scientists of the day, not at all to his discredit.

During this study of twenty years he constructed some nine solar engines. In the earlier ones he used the sun's rays to heat air but found the mechanism too cumbersome. A small hot air engine suggested by it has been immensely successful, however.

Later on he favored using the concentrated solar rays to make steam, and his latest model on a very large scale was mechanically a conspicuous success.

Ericsson was primarily a draftsman. For nearly seventy years, every day in the year, he labored over the drawing board, seldom less than twelve hours a day. Is it a wonder that the output was prodigious? His drawings were remarkably accurate to the minutest detail and needed only to be implicitly followed.

In constructing novel war ships under rush orders, work would be begun with the first drawing and be carried on simultaneously in a dozen different shops and yards.

As an inventor he was versatile and prolific, running ahead often of his ability to construct. His name stands principally for the hot air engine, the steam fire engine, surface condenser, the screw propeller, the turret, armored war vessel, the automobile torpedo and the solar engine.

He was a notably great engineer, but his peculiar mental make-up, keeping him at continual odds with his contemporaries, prevented him from being as useful and as honored as otherwise would have been the case.

As an engineer he saw things as he thought they ought to be, rather than as they are. He was a mechanical "seer" and therefore forever at war with the faulty present. He seemed to comprehend the essentials of a problem at once and to proceed directly to the simplest solution. He made constant use of mathematical com-

putations as a basis and test of his designs, and rarely failed to convince when he was willing to explain.

He came to have unlimited confidence in his own judgment and something of contempt for that of others.

In one of his letters he said that "he supposed Providence had endowed him with greater abilities than any other mortal."

He was a Swede of the Swedes, tall, strong, honest and intensely patriotic, but a man of hasty, ungovernable temper, of a proud, passionate spirit that resented the least interference.

Finding so few congenial associates he more and more withdrew himself from society and lived the life of an eccentric and hermit. Sticking so closely to his drawing board, year after year, never mingling with others, or keeping posted as to the work of others, he lost the advantages of criticism and comparative study and paid the penalty of his isolation.

He made a great deal of money and spent it lavishly on his experiments, generously on his friends, sparingly on himself. He died in 1889, aged eighty-six years, and with the passing of the years his frailties are more and more forgiven and his genius recognized.

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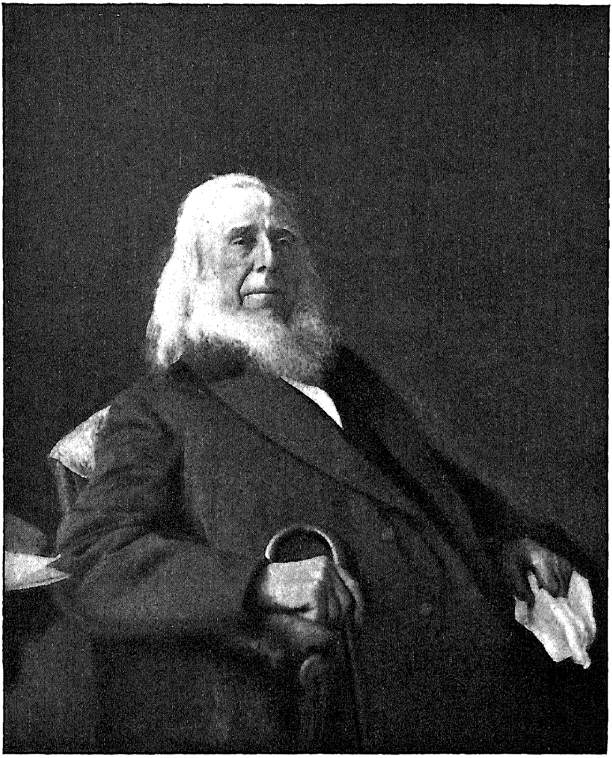

Peter Cooper
1791-1883

By the kindness of
Dr. R. W. Raymond

Peter Cooper.

▼ ▼ ▼

Peter Cooper was born in the city of New York in 1791. His ancestors on both sides were men of comparative wealth and worth. During the Revolution his father and maternal grandfather occupied places of rank in the patriot army. After the war his father made hats, successively in New York, Catskill and Brooklyn. Finding this unprofitable he sold out and bought a brewery, first at Peekskill and then at Newburg.

Peter followed his father and worked with him until seventeen years old, when he became apprenticed to a coach-maker in New York. Up to this time he had had but a few months' schooling, but was industrious, bright, and eager to learn. Although he had his full share of boyish spirits, he had character enough to resist the temptation to idleness, and used every opportunity to increase his knowledge and skill. He fitted up a room as a workshop where he lived, and gained considerable skill as a wood-carver. He devised a machine for mortising wheel-hubs that was the first of its kind in the country. He also invented a tide-mill and a compressed-air motor for ferry-boats. During this time he received his acquaintance with apprentice boys, their ways and dangers and needs, that was the seed of which Cooper Union was the fruit.

When he was twenty-one, his employer offered to

set him up in business as a coach-builder, but he declined. Instead he went to Hampstead, Long Island, where his brother was, and engaged with a man who was making machines for shearing cloth. Here he found also the one who, for nearly sixty years of married life, proved to be an ideal wife, industrious, wise and sympathetic. In his old age he called her "his guardian angel."

In three years he saved enough money to buy the right for New York State and commenced the manufacture of these shearing machines on his own account. It proved very successful for a time, owing to certain improvements that he made, until the demand for American cloths died out after the War of 1812.

The principle of this improvement was the same as the one now universally used in mowing-machines. He made a model of a machine for the latter purpose and used it to cut grass in his yard long before others made and patented similar machines.

With the passing of the demand for his shearing-machines, he turned his shop into a furniture factory and then sold it for what he could get.

At thirty-three he purchased a lease of property in New York, where the Bible House now stands, opposite the Cooper Union, and began selling groceries. Three years later he leased a glue factory and began making glue, oil, whiting, isinglass, etc. After twenty years in this location, he removed the business to Brooklyn, where it is still continued. This was the most profitable of his early ventures and the foundation of his fortune. His many contrivances improved and cheapened the product, while his industry and application (he was for many years his own superintendent, bookkeeper and salesman) built up the business until he had a practical monopoly of the

trade in this country. Speaking of these early days he said, "I was always planning and contriving, and was never satisfied unless I was doing something difficult, something that had never been done before, if possible."

In 1828 there was great excitement over the building of the Baltimore & Ohio Railroad. Peter Cooper was led by two men into a land speculation. They deceived him as to their financial ability, and he was later obliged to carry the whole. He thus came into the possession of 3,000 acres of land within the limits of Baltimore.

To make some use of the property he erected upon a part of it the Canton Iron-Works. The ore he dug from one part of the land, and the charcoal he made from wood on another part. In this venture he showed his characteristic audacity. He designed and built novel kilns of a spherical section twenty-four feet in diameter and hooped with iron. The venture was only partially successful, but it gave him an introduction to the iron business, with which he was ever after so largely identified.

Within a year he sold out the iron works and determined to sell the balance of the land for the first offer he received. The first offer proved to be nearly as much as he had paid for it. He accepted it, and took a large part of his pay in stock at 40. This stock began to advance at once, and in a short time he closed out his holdings at 230.

Meanwhile the promoters of the B. & O. R. R. were becoming discouraged over the difficulties they encountered. At last about thirteen miles of road were constructed, but the nature of the country forced them to make curves with radii as low as 400 feet, and grades of eighteen feet to the mile. English practice made 900 feet the limit, and predicted failure for anything less.

Cooper.

When the fortunes of the road were at their lowest ebb, Peter Cooper volunteered to make a locomotive that would successfully run the curves and haul loads. He used a small brass cylinder, of 3¼ inches bore and 14¼ inches stroke. His boiler was 20 inches in diameter, and about 5 feet high, half of which was fire-box, the balance with two, perhaps more, vertical tubes made from musket-barrels.

At first the connection to the wheels was made by a device patented by him in 1828 to transfer reciprocal motion to axial by means of an endless chain and a prod and a hook on the piston-rod.

This was tried in 1829, but was not very successful, so Cooper substituted the usual crank motion for the endless chain, and employed gearing to increase the speed. This was tried in 1830, running the thirteen miles one way in 72 minutes, and the return in 57 minutes. The locomotive weighed about a ton and carried about four tons, including one car and forty-two persons. Anthracite coal was used, with fan draft. The engine developed about 1.43 horse-power, and was run for two or three weeks. The interest in this diminutive locomotive lies in the fact that it was the first actual locomotive used in America. It lost a contest with an old gray horse, drawing a load on a parallel track, but proved enough to revive interest in the railroad and carry it to ultimate success.

During these years Mr. Cooper had been interested in many other things. He developed his tide-mill to compress air, and then to drive an endless chain two miles long set up on poles in the East River. His purpose was to prove the feasibility of driving canal boats in the Erie Canal, then building, by means of an endless

chain, in the bed of the canal, to be operated by the overflow and fall of water to different levels of the canal.

His experimental chain in the East River was a success, and Governor Clinton, who was one of those who visited it, gave him $800 for the right to use the invention in the canal. It was never employed there, but the principle has been proven very successful on the Rhine and other European rivers.

Another of his inventions was a marine torpedo, to be operated from shore by two steel wires. One was built, but an accident broke the wires and he abandoned the experiment. Another was a plan to utilize the explosive power of chloride of nitrogen in aerial navigation.

Still another was a series of buckets, or cars, carried on an endless track up to a sand-bank on one part of his Baltimore property. The sand was thrown into a hopper placed over the moving cars, which was then carried and dumped in a valley he wanted to fill. The cars returned bottom-side up on the under side of the track. This device, which is common enough now, was quite novel in 1827.

After closing out his Baltimore property, Mr. Cooper started a machine-shop in New York city, which he leased in a year to another. Then, after two years, owing to the failure of the lessee, he was obliged to take it on again. He made it over into a rolling-mill and wire factory, and ran it for several years. Then he removed it to Trenton, N. J., and greatly enlarged it.

In successive years he added to its equipment by the erection of the largest blast furnaces then known, at Phillipsburg, the purchase of the Andover mines, for which he built a railroad of eight miles over a rough country to bring ore down to his furnaces at the rate of

40,000 tons a year, and the purchase of the Ringwood property of 11,000 acres of coal and iron lands. This was formed into the Trenton Iron Company, and later redivided, a part going under the name of Cooper & Hewitt.

Peter Cooper was fortunate in having at this time a son, Edward Cooper, and a son-in-law, Abram S. Hewitt, who were able and ready to assume the immediate charge of the iron works, which, under their combined oversight, developed for a time into the most progressive works in the country. There was tried the Bessemer process (1856) for the first time in America; there were rolled also (in 1854) the first iron beams for structural purposes; and, later on, they were pioneers in trying the open-hearth furnace and the use of basic linings.

So great were the services of Peter Cooper and Abram S. Hewitt in the early development of the steel industry of the United States that each received from the Iron and Steel Institute of Great Britain the famous Bessemer gold medal.

As early as 1850 Mr. Cooper became interested in the inventions of Cyrus Field, and in 1854 became president, which office he held for twenty years, of the New York, New Foundland & London Telegraph Co., organized to lay an Atlantic cable. Through all the vicissitudes of this company Peter Cooper was the prime mover. His faith was unwavering, his energy persistent, and his credit the foundation of the ultimate success of the enterprise. This was, in the end, perhaps the most profitable of all his undertakings, a well-merited reward for his faith and effort.

As early as 1810, when Peter Cooper was an apprentice in New York, he had his first desire to do something

for the apprentice boys of that city. It became a fixed purpose in his life at that time, but did not take form until about 1828, when he was in the grocery business. At that time he had a conversation with a gentleman who had recently visited a polytechnic school in Paris, and who was enthusiastic about its advantages to working boys.

He determined at that time to found a similar institution for the working boys and girls of New York. To this end he began buying land in the block at the junction of Third and Fourth Avenues and Eighth Street. The purchases were completed about 1854, and he began the erection of the building. It was a large building at the time, of six stories, built of brick, stone and iron, and required several years for its completion. The building is notable in several respects. The great audience-room is in the basement; it includes elevators, and required for its construction iron beams, which were rolled at his Trenton Iron Works, the first in this country. The land and building cost $630,000, and was designed to accommodate, besides the great audience-room, a large reading-room, museum, library, a great many class-rooms and laboratories, and, on the street floor, stores, whose rental would be an income for the support of the classes.

His object was to provide an institution where free instruction could be given in all practical and artistic branches to working boys and girls. He called it the Union for the Advancements of Arts and Science, his desire being that his gift should be only a nucleus to which others would add their gifts, but the Legislature, in granting the charter, changed the name to the Cooper Union.

From the beginning the institution had the advantage of Abram S. Hewitt's great organizing ability. Still it was especially the child of Peter Cooper. He visited

the building daily, and as years passed by he loved nothing better than to sit on the platform evenings to enjoy the lectures and discussions. He would spend hours with the superintendent of the building, arranging for the better accommodation of the increasing classes. He would come with visitors, great men of wealth and position, and after showing them the equipment and the usefulness of the plant, make oportunity to urge upon them the duty and pleasure of every rich man doing something in a public way for the education and uplifting of the common people.

Among the many he thus met and influenced were such men as Marshall Field, A. T. Stewart and Andrew Carnegie. The latter has publicly declared that he received his strongest incentive to philanthropy from the words and example of Peter Cooper. Mr. Carnegie has emphasized his indebtedness by a gift of $600,000 to the endowment of the Union. The children and friends of Mr. Cooper have added their gifts, until now the endowment, and the 3000 students require the entire building. The great hall has given voice for forty years to the expression of public opinion on all the vital questions of the day.

Mr. Cooper, as early as 1825, began to show an interest in civic affairs. The present efficient organization of the public schools, the fire department and water supply are largely the result of his untiring zeal. He was deeply interested during the Civil War in national affairs, his interest taking the practical form of running his iron works on government orders at the smallest profit. He loaned his money to the government freely and actively promoted expression of the public opinion that marked

the turning point of the tide, and the second election of Lincoln.

After the war he identified himself with the "greenback" party, and was their nomination for President of the United States in 1876. His stand in this regard is looked upon by his friends as a mistake that was to be explained by declining powers incident to old age, and his intense sympathy with the common people and their troubles.

His was a noble life. At a reception given in his honor in 1874, when he was eighty-three years of age, he said: "While I have always recognized that the object of business is to make money in an honorable manner, I have endeavored to remember that the object of life is to do good."

Nobly and truly he lived up to this reasonable canon. His audacious energy never led him far astray, checked as it was by the soundest of good sense and the kindest of temperaments. He died in 1883, aged ninety-two years, and his almost unprecedented funeral showed but inadequately the loving regard of his fellow citizens.

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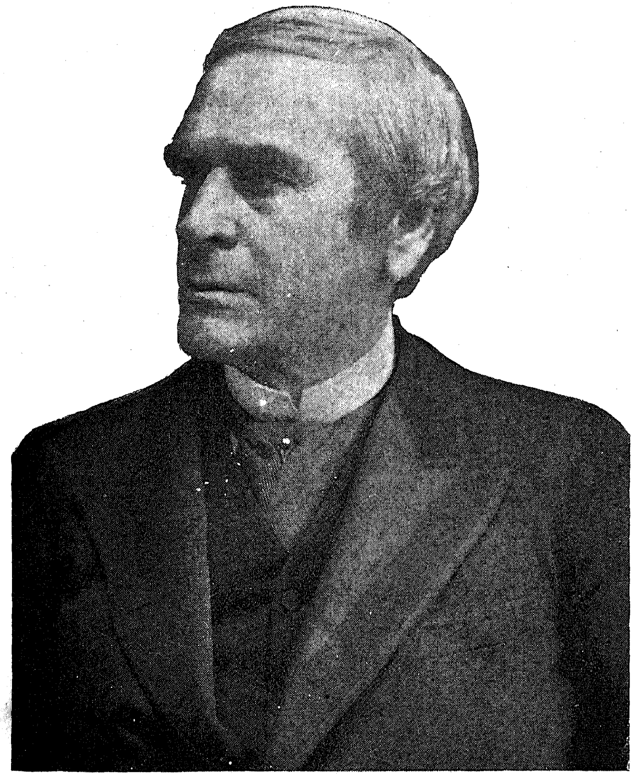

George H. Corliss

1817-1888

Presented by
E. K. Hill Esq.
Corliss Steam Engine Works

George H. Corliss.

▼ ▼ ▼

The name of Watt easily takes the place of first importance in the history of the steam engine—and probably the name of George H. Corliss would, by general consent, be given the second place. The importance of his inventions, and the excellence of his engineering achievements, is remarkable when we consider how little his inheritance and his early associations contributed to that end.

His father was a country physician—rather noted for his surgical skill, which probably explains the mechanical instincts of his son George.

George was born in 1817 at Easton, Washington County, New York. He had a good country school education, and attended an academy at Carleton, Vt., for a time. In after years he related that he studied the elements of algebra while watching with a gun, for a woodchuck to come out of his hole. In 1837 he was clerking in a country store at Greenwich, N. Y., during which time an indication of his mechanical and executive ability showed itself. A spring freshet carried away the only convenient bridge. The local builders declared it impossible to erect even a temporary bridge for weeks to come. Young Corliss constructed an emergency bridge in ten days at an expense of only fifty dollars. This country store was in connection with one of the early cotton factories, and part of his work was to measure the cloth from

the mill. It was a place of considerable responsibility, for young Corliss apparently had the entire charge of this and of selling all sorts of goods "on account." The next year he opened a country store of his own, but soon tired of it and sold out in less than a year.

Up to this time he had not seen the inside of a machine shop, and had no especial interest in that direction. It must have been very soon after, however, that he became interested in the possibility of constructing a sewing machine. He invented one and secured a patent in 1842. This was some years before Howe secured his patent. Corliss' device passed needles and thread through in opposite directions at the same time. To perfect this invention and to arrange for the construction, Corliss went to Providence in 1844. The Company to whom he went—Fairbanks, Bancroft & Co.—then doing a machine and engine business, were not long in recognizing his talent, and in persuading him to drop for a time his sewing machine, and enter their employ as a draftsman on engine designs. Within a year he was admitted to the firm, and within two years he had made the invention that revolutionized the construction of steam engines. Corliss was at this time, 1846, only 29 years of age. In 1848 he entered into a partnership under the name of Corliss, Nightingale & Co., and this company built the first engine embodying these improvements. This company was incorporated in 1856 as The Corliss Steam Engine Co. His original patent was dated 1849, but was re-issued in 1851 and again in 1859.

Hitherto all engines were controlled by a throttle valve that could only be varied in its operation by hand. As such a valve was necessarily some distance from the cylinder, the waste of steam was considerable, and it was

impossible to operate it quickly enough to cut off steam during a part of a stroke. Mr. Corliss' invention was the combination of a regulator with a liberating valve gear and sliding valves. It did away with the wasteful throttle valve, placed the valves close to the cylinder, automatically opening and closing them, within limits, at any point of the stroke, thus allowing the steam to be used expansively. The first one constructed was a beam engine with a diameter of 30 in., stroke of 6 ft. and indicated 260 H. P. It had four flat slide valves, the two upper for supply and the two lower for exhaust.

The transmission was by rods and toothed segments from a central disc operated by a crank and rod from an eccentric on the engine shaft. The cut-off was controlled by a trip operated from the governor and adjustable within limits at pleasure and automatically by the governor. When the catch was thrown out the valves were closed by weights with a dash pot to prevent excessive jar. This device permits the valve motion to act rapidly while opening and closing a port, and yet to move slowly in approaching the port and after it is well opened, thus securing ample port openings, permitting full admission and very slight frictional resistance. The construction of this engine was followed by two others of the same size and all were so successful that land was purchased and extensive works erected.

The second type substituted cylindrical for flat slide valves, which have since been characteristic of all of the Corliss valve gear. They were first used on a horizontal engine built in 1850.

The third type was designed in 1851 or 1852. It has cylindrical valves operated by rods from the central

reciprocating disc. The trips were the well known "Crab Claw" and weights were used to close the valves.

This was the type first known in Europe and was the starting point for all later variations. In 1858 he invented a fourth valve gear which was not patented, and which is now seen in what is known as the Harris-Corliss type. The difference was in the manner of tripping the cut-off and the working of the valve lever.

A fifth type was exhibited for the first time at the Paris Exhibition of 1867. The fundamental construction was the same, but in detail the mechanism was entirely new. The most noticeable innovation was the substitution of springs for weights in closing the valves. This was really patented as early as 1859 but became generally known only after the Paris Exhibition.

A sixth form was designed in 1874 and 1875. The valves were closed by atmospheric pressure, weights or springs being no longer used. The reciprocating disc was centrally placed, but the operating rods were mounted in pairs, using two pins, instead of four, as formerly.

There was a seventh variation also but it was relatively unimportant, except that the disengagement was more exact and certain.

In 1880 an eighth valve-gear was designed and put on the market. This is known as the "wrist-lever type" of valve-gear.

Mr. Corliss anticipated the demand for higher piston speeds and saw that this would necessitate larger port openings, in order to get the highest efficiency from the steam. To get the full benefit of the larger port openings, it was necessary to operate the steam and exhaust valves much more rapidly than in the valve-gears in general use. This he accomplished by his improved wrist-lever type

of gear, which he designed and built in 1885 and 1886. This, without question, was the best and most efficient Corliss type of valve-gear and is still exclusively used on the Corliss engines built at the original Corliss Works.

This invention of the automatic cut-off was a far reaching improvement. It so approved itself that the Corliss principle is seen in a majority of the steam engines built since his day. It was found to be extraordinarily satisfactory and economical. Mr. Corliss himself had such faith in it from the beginning that he did not hesitate to accept in payment for his engines a proportion of the guaranteed savings in coal consumption. Some of his guarantees seemed wildly extravagant, but he was always able to do better than he promised, and usually to his financial advantage.

Mr. Phillips, an old associate of Mr. Corliss, gives several instances of such guarantees:

"In 1855 he put an engine and boilers into the James Steam Mill at Newburyport, Mass., the price for engine and boilers to be five times the amount of coal saved in one year. The old engines, which were 24 x 48 (condensing developing about 180 H. P.) used on an average for the five years preceding Mr. Corliss' contract, 10,483 lbs. of coal per day, and were fair examples of the engines in use before Mr. Corliss' time.

"The new engines were found to use but 5,690 pounds per day, making a saving in a single year of $3,946.84, coal being reckoned at $6.00 per ton, making the total price paid to Corliss & Nightingale for a 180 H. P. condensing engine and boilers, $19,734.22."

"In 1856 a new engine was put into the Ocean Steam Mills in Newburyport, Mass., Mr. Corliss agreeing to take the old engines (which previous to this were

considered by the owners first-class machines) and the saving of fuel in two and one-half years, or the sum of $3,000 cash. The Mill Company decided (having doubtless in mind the experience of their neighbor, the James Steam Mill) to pay the $3,000, a wise decision, as the saving amounted to that in two years."

"In 1852 a new engine was put into the rolling mill of Crocker Brothers & Co., in Taunton, Mass., guaranteeing to do one-third more work than the old engine was doing, and when five tons of coal was used per day, but two tons should be used to do the same work. Forfeit $1.00 per pound for every pound per day used above that amount. Another contract which sounds hazardous but which shows the faith which Corliss and his partners had in the engine, was that made with the Washington Mills at Gloucester, N. J., wherein they agreed to put in an engine of about 200 H. P. for the sum of $7,100.00 and forfeit $5,000.00 for each ton per day of coal above four tons which should be used in driving the mill. This contract was entered into knowing that about nine tons per day were used with the old engines."

This type of engine was particularly valuable to cotton and other mills where regularity of speed was essential. In spinning, especially, it was necessary to have an even speed. If the speed increased it resulted in broken thread. If it decreased it resulted in diminished production. The control was so sluggish, with the old type of engines, that the engines were run at a comparatively slow speed, in order that they could be throttled before they reached so high a speed as to be disastrous. The Corliss engine could be safely speeded to the highest rate permissible, without danger of racing; so effective was the regulation that a variation of work from 60 H. P.

to 360 H. P. within a minute did not perceptibly affect the speed of the engine.

Probably the engine that brought Mr. Corliss the most notice was that built for the Centennial Exhibition. It would not be considered large in these days, but at that time it was counted extraordinarily large. Mr. Corliss was one of the original members of the Executive Committee. He suggested that they secure a single engine to furnish all the power necessary for the exhibition, but the others thought it a too hazardous undertaking, but later—after being unable to make satisfactory arrangements otherwise—they accepted Mr. Corliss' proposal and authorized him to construct such an engine. The engine had two upright cylinders 3′ 4⅞″ in diameter, with ten feet stroke. The beam was 27′ 1⅞″ between centers and weighed twenty tons, and was suspended 30 feet above the floor. The connecting rods were 24 feet long. The fly wheel was 29′ 10″ in diameter, two feet face and had 216 teeth. The pinion was 9′ 11½″ diameter with 72 teeth. The crank shaft was 18 inches in diameter. The cylinders were double jacketed. The entire engine weighed over 600 tons. They ran on 30 pounds pressure, the shaft making 36 revolutions, and could develop 2800 H. P., although they were called upon for only about 1000 H. P.

It was placed in the center of Machinery Hall and ran without a hitch from begining to end. Its starting and stopping marked the hours of opening and closing the exhibition. The engine was built in nine months and 26 days at a very large expense to Mr. Corliss above the amount received from the management of the Exhibition. It attracted the attention of every one, not only for its imposing and beautiful design, but for the excellent work-

manship and its silent, regular running. It seemed to mark the acme of all the wonderful engineering works gathered together from all the world.

As time passes a larger measure of credit is given to Mr. Corliss for his invention than was granted by some of his contemporaries. For fifteen years after he began construction, his road was beset with legal difficulties. His patent was granted in 1849, and almost immediately he was opposed by owners of patents granted to Frederick E. Sickels in 1842 and 1845. Both sides engaged the best lawyers in the country, and every charge and counter-charge was bitterly contested.

Mr. Sickles gained his experience in marine engine construction, and very unwisely limited his patented claims to lifting, tripping and cushioning puppet valves. Corliss claimed the same for slide valves. Sickels devised a water dash pot to cushion his valves. Corliss devised an air cushion to prevent the weight that closed the valve from slamming.

Sickels' invention enabled him to cut off the steam at any point of the stroke, but this cut off was adjustable only by the hand of the engineer, and according to his judgment. Corliss' invention enabled him to cut off the steam, up to half the stroke, automatically, by the nice precision of the governor.

Asa Gray, President of the American Academy, said to him, on presenting the Rumford Medal, "Your engine embodies within itself a principle by which it appropriates the full, direct and expansive force of the steam and measures out for itself at each stroke, with the utmost precision, the exact quantity necessary to maintain the power required."

At the time he was with Nightingale, Mr. Corliss

made an unsuccessful effort to apply his principle to the locomotive. A reference is made to it in the story of Alexander Holly, who was a draftsman at the time, with Mr. Corliss. There are reasons why the principle is not applicable to locomotive or marine engines, but for stationary and pumping engines, it is the first and perhaps the best.

Mr. Corliss has invented other machines, notably a gear cutter, and his engineering ability is seen at its best in the large number of heavy, special machine tools which he designed for use at his engine works. They are being used to-day and hold their own in comparison with the most modern.

He built a number of large pumping engines and at one time engaged in a prolonged duel with the municipal grafters of Boston over a contract for sewage pumping engines. Mr. Corliss' proposition was for four engines having a guaranteed duty of 90,000,000 foot pounds, with boilers and all appurtenances, erected complete, for $180,000. Instead, a contract was placed which cost the city of Boston some $475,000. Mr. Corliss offered a guarantee of service far in excess of the favored choice, and to convince, offered to construct and operate at his plant, and at his expense, one of these engines, before proceeding with the contract.

In Mr. Corliss was a rare combination of conservatism with apparent venturesomeness, but his uniform success proved that his venturesomeness was not inconsistent with conservatism, but was based on knowledge and wise faith.

His engineering judgment was quite remarkable, and was well matched by an equally sound financial sense. For an inventor he was singularly under self control. He

would doubtless have succeeded in any line of engineering, but having given his mind to engines, he refused to be drawn off to anything else. He was big enough to discern the possibilities of his department and to develop it to keep pace with his own growth.

Personally, he was always courteous, but somewhat reserved, and a strict disciplinarian, although genial and approachable to his friends and his humblest employee could always approach him with as much ease as any officer of his company and always feel assured of the same courteous attention.

One of his mottoes in business was, that "The highest standard of workmanship and the best materials of their respective kinds," were the only ones to be considered in the manufacture of his products. His sterling character was as much in evidence in private life as in business. His contributions to educational and charitable objects were not only most liberal, but always, in a marked degree, cheerfully given, although known only to his immediate family and the recipients. He was a devoted Christian in the highest sense of the term.

There is a story told that illustrates the benevolence of his character: At the time the workmen began to break ground for the pumping works at Providence, they disturbed a nest of young birds and Mr. Corliss had them move to another part of the grounds for a few days until the young birds were able to take care of themselves.

His clearness of mind is seen in his business correspondence, in law cases, in the brevity of his patent claims, and in the grasp of affairs generally.

He was highly honored by his townsmen, engineering associates and scientific associations.

He received a gold medal at the Paris Exhibition of

1867 in competition with over a hundred other engine builders. He received the Rumford Medal from the American Academy of Arts and Sciences in 1870. Although not an exhibitor, he was given a Grand Diploma of Honor at Vienna, in 1873, because his improvements were seen in so many of the different engines exhibited. The Institute of France gave him, in 1868, the Montyon prize and in 1886 the King of Belgium made him an officer of the Order of Leopold.

He was a state senator in 1868, 1869 and 1870 and a presidential elector in 1876.

He died in 1888.

Probably no single inventor since Watt has enhanced the efficiency of the steam engine as did he. When we consider the part that the steam engine has played in modern economics, this is a high distinction, indeed.

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Alexander Lyman Holley

1832-1882

Alexander Lyman Holley.

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In the memory of the engineers whose generation is now passing, the personality of Alexander Lyman Holley stands out in fair colors. His enthusiasm was contagious, his genial good-fellowship irresistible, and his eloquence captivating. But these qualities were of but passing value except allied, as they were in him, with those other qualities of intellect and character that made him not only singularly attractive, but exceptionally effective in the material development of our national life. His ancestors were well-to-do Connecticut folk. His father, at one time Governor of the state, was a manufacturer of cutlery in the small village of Lakeville, in Salisbury, Conn. Alexander was born there in 1832. As a boy and young man he was full of sports and jollity, a leader among his fellows in adventure and daring. He enjoyed school and study when it had to do with the sciences, but had a corresponding distaste for it when it had to do with languages and the classics.

He studied successively in village school, academics, private tutor and Brown University. He revealed very early a natural talent for keen observation, with an unusual ability for recording the same in writing and drawings. When missed from sight he was usually to be found near some steam engine or other machinery, drawing the parts to be sure that he thoroughly understood them.

Some of his sketches made when only nine years of age, on a visit to Niagara Falls, are still extant, and are creditable to the draftsman. From this time on his letters are filled with descriptions, sketches and comments of the engines and machinery that he has seen.

He also found increased interest in writing and discussion. At 17 he had made a list of essays that he had written, and was publishing one "paper" called "Guncotton," and another called "Locomotive," beside sending contributions to other journals. One of his essays, 1850, was an exhaustive description on the manufacture of cutlery, in which he gave in detail a "description of the mechanical, chemical and manual operations performed on certain raw materials to convert them into the means, implements and materials for manufacturing pen and pocket knives." This was but the beginning of a long and varied list of essays, descriptions, editorials, books and orations, with which he filled his life to its close.

He graduated from Brown in 1853 with honors. He had already passed from being an interested observer of steam engine construction into the ranks of the participants. In 1851 he invented an excellent cut-off and an oscillating engine, neither of which were patentable, owing to the broad claims of previous inventors. His graduating oration was on "The Natural Motors," and he entered at once the employ of Corliss & Nightingale for the production of a locomotive. He worked as draftsman, machinist, and subsequently ran this trial locomotive until it proved to be unfit. In later years in one of his felicitous after-dinner orations before the A. S. M. E., he referred to this locomotive as being a cross between Mephistopheles and a Colorado mule, having an inborn cussedness. Strange to say, she showed excellent indica-

tor cards, and he went on to say: "Well, once in a while, when she had been jackassing over the road about four hours behind time, and we had pinched-barred her into the round-house, we used to pull out these indicative cards and talk them over right before her, and we would look at her and ask one another why in thunder an engine that could make a card like that would act as if the very old-chief engineer was in her. And next morning she would rouse up and pull the biggest train that ever had been over the road, ahead of time."

Corliss gave up making locomotives with this, and so Holley left, too, for his heart was in them. He traveled through the country trying to obtain employment in some locomotive shop, until when completely discouraged he was taken on at Jersey City. While working here in 1855 he married happily.

While at work for Corliss he had written articles for Colburn's Railway Advocate, and through them was brought to the attention of Zerah Colburn. This brilliant engineer and editor was attracted to Holley, and from being a contributor to the Advocate he became editor and partner. In 1856 he was sole editor and owner. Then for several years he threw himself heart and soul into journalistic work. He traveled over the country, became acquainted with every engineer of note, and every phase of railroad progress, but the paper failed. Then in 1857 Colburn and Holley went to Europe and made a careful study of European railroad practice, the results of which were preserved in a sumptuous folio. This book was not a mere description and compilation of data, but entered into a minute comparison of mechanical construction, an analysis of costs, and finally traced the British superiority of the day to the credit of a super-

ior road-bed. Colburn's part was probably the greater in this work, but Holley did much, and the work which followed, "Railway Practice in America," was altogether his.

Holley became now a correspondent of the N. Y. Times, sending in over 200 articles between 1858 and 1863, which attracted attention and which gave the Times the highest position of authority on engineering topics which a daily newspaper ever occupied.

In 1859 he made a second trip to Europe and in 1860 a third, dividing his writings between the Times and the American Railway Review, of which he became mechanical editor. He also secured patents for a variable cut-off and a rail chair. He was also mechanical editor for Webster's Dictionary, and assisted E. A. Stevens in locomotive changes on the Camden & Amboy R. R.

At the breaking out of the Civil War in 1861, Holley offered his services as an inspector of steamboats, or any other position where his engineering experience would be of service. Although endorsed by a splendid list of great engineers, politics lost him an appointment, and left him free to continue his editorial work.

The Stevens Battery coming into prominence owing to the war, Holley was asked by Mr. Stevens to make an expert examination, and later to make a trip to Europe to gain information as to the best use to make of it. This gave Holley the opportunity to make an exhaustive study of everything connected with war ships, ordnance and armor. The results were embodied in 1864 in a large volume that became an authority in its department.

Before this work appeared Holley had become interested in another direction that was to lead him into a field from which he was to gather his brightest laurels.

He was sent to England in 1863 to investigate the Bessemer process for making steel. It had been tried in an experimental way by Cooper & Hewett, but with them, as in England, the difficulties encountered had proven to be a serious setback to its introduction. Alexander Holley's keen observation recognized the inherent value of the process, and he secured for his clients the sole American license.

He returned, was admitted to the firm of Griswold, Winslow & Holley, and began in 1865 the construction of a Bessemer steel plant at Troy, N. Y. From this time on his energies were largely given up to the engineering problems of this process. In 1867 he designed and built the works at Harrisburg, Pa. Then in 1868 he rebuilt the works at Troy.

In the years that followed he designed the works at North Chicago, Joliet, and the Edgar Thompson works at Pittsburgh. The latter he valued as his most conspicuous success.

Then the licensees formed themselves into an association of Bessemer steel manufacturers, of which Holley became the consulting engineer. In this capacity the works at St. Louis, Cambria, Bethlehem and Scranton were built. Holley, more than any one else, is to be credited with the marvelous practical and commercial success of this process, and all the train of resulting benefits, cheap railroads, bridges and general construction that made this the age of steel.

Mr. Robert W. Hunt, in speaking of Holley's preeminent services in enormously increasing the production and cheapening the cost by the high excellence of his general plans, credits him with the following particular improvements: Raised furnaces and converters, top

supporters, hydraulic cranes, use of three ingot cranes, location of converter in relation to pit and furnaces, improved ladle crane, a single operating point for all cranes, ladles and converter, use of cupolas instead of reverberatory furnaces, an intermediate, accumulating ladle placed on scales, an improved ladle bottom. These were not all that he contributed, but were the most radical and conspicuous.

These improvements, together with the contributions of other engineers, raised the output per unit fifteen fold. The success of this invention of Bessemer probably had a more profound effect upon the social fabric than any other single proposition except the invention of the steam engine, and a large part of its practical success is due to Alexander Holley. Hitherto he had shown mainly his critical acumen; in this he revealed equally great creative faculties. He received in all sixteen patents, ten of which refer to improvements in the Bessemer process, the last of which, made almost on his death-bed, was for a removable shell for the converter, to be used especially for the newly introduced basic lining.

While always loyal to the Bessemer process, his interest did not end there. He gave much thought also to the Siemens-Martin open-hearth process, and the furnaces of this style built, with him as consulting engineer, were for some time the finest in the country. He believed in the Pernot furnace, the Thomas-Gilchrist patents and the basic lining, and had an influential part in their practical introduction.

With his entrance into constructive engineering practice, he by no means gave up his literary labors. In 1869 we find him editor for a year of Van Nostrand's Eclectic, while his contributions to general magazines and

technical journals were continuous. His confidential reports on Bessemer practice continued for many years, sent only to members of the Bessemer Association, were said to be a mine of accurate information, and of highest literary merit. He collaborated on an extensive series of illustrated articles on American iron and steel works for the London Engineering.

He wrote notable articles for mechanical encyclopædias, and a steady stream of technical papers and addresses for the various scientific societies of which he was an honored member. His literary style was graphic, clear and often brilliant, which made even his most technical essays interesting.

He was a member of a government commission on standard tests, and of the Board of Judges of the Centennial Exhibition.

In 1865 he was elected a trustee of Rensselaer Polytechnic, and always after had a deep interest in technical education. In later years he delivered lectures on metallurgy and engineering subjects before the Columbia School of Mines and Stevens' Institute. He was president of the Institute of Mining Engineers in 1875, a vice-president of the Civil Engineers in 1876, a founder of the American Society of Mechanical Engineers, a member of the British Institute of Civil Engineers, the Iron and Steel Institute, and a recipient of the Bessemer gold medal.

At the meetings of these scientific associations his genial good-fellowship, his always interesting and instructive professional papers, and his capital after-dinner speeches, won him a most hearty welcome.

One of the most praiseworthy results of his influence was the *esprit de corps* that he infused into the engineer-

ing profession. It was he who suggested and brought about the practice of uniting pleasure with business at the meetings of these societies, by planning for excursions to convenient points of interest, workshops and engineering enterprises, and also the habit of inviting the wives to accompany them on these trips. No banquet was complete without some poem or speech from Holley.

He had a charming presence, a pleasant voice under perfect control, and an always felicitous choice of words. His wit was genial and sparkling, leaving no sting behind, and gliding naturally and easily into the technical and thoughtful.

He loved pictures, scenery and art of every kind. He was himself no mean architect and artist. It was he who designed the beautiful Charter Oak chair, now preserved in the State House at Hartford.

His habit of careful observation, trained from childhood, placed him in possession of an immense fund of information. It was his habit, also, to make elaborate notes of his observations, and to preserve them in carefully indexed note-books.

He was an engineer rather than an inventor. He had a brilliant, versatile intellect, a genius for hard work, indomitable perseverence, and bouyant enthusiasm. This very evident ability, together with those other qualities of heart, his modesty, his friendly sincerity, his perfect willingness to give more than he received, a loving disposition and a sunny temperament, bound his associates to him with the rarely combined bonds of admiration and affection. He was fairly loved by his associates. His fund of accurate information, his engineer's passion for truth, his correct judgment, together with his transparent sincerity and attractive personality, gave him an unusual

influence over men. There was no place in his great heart for professional jealousy.

He was an acknowledged authority by mechanical, civil and mining engineers alike, and capitalists entrusted their millions to him in perfect confidence.

He began life in perfect physical health, but his habit of intense and prolonged application told on him at last. As early as 1875, when only forty-three years of age, he began to feel the effects of the enormous strain. He was seriously ill in 1881, but recovered only to collapse again in 1882, from which he never rallied.

Unconsciously he pictured his own end one night at Pittsburgh, when he had been called from a sick bed to respond to a gift of plate from his associates. What could be more beautiful and pathetic than his closing words on that occasion:

"Among us all who are working hard in our noble profession and are keeping the fires of metallurgy aglow, such occasions as this should also kindle a flame of good-fellowship and affection which will burn to the end. Burn to the *end!*—perhaps some of us should think of that, who are 'burning the candle at both ends.' Ah! well, may it so happen to us that when at last this vital spark is oxydized, when this combustible has put on incombustion, when this living fire flutters thin and pale at the lips, some kindly hand may 'turn us down,' not 'under-blown,' —by all means not 'over-blown'—some loving hand may turn us down, that we may, perhaps, be cast in a better mold."

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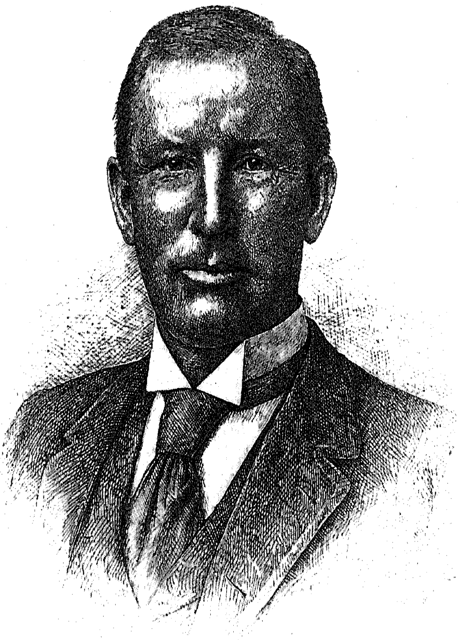

William Richard Jones

1839-1889

William Richard Jones.

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"The most important man in the Carnegie scheme." Such is the high praise given to William R. Jones. He was *par excellence* a captain of industry. His father was a clergyman, who came to this country from Wales in 1832 and was located in Pittsburgh and Hazleton, Penn. William, his eldest son, was born in 1839. His father died when he was quite young, so that he was forced to begin work with a very limited schooling.

He was apprenticed to the Crane Iron Company of Catasauqua when only ten years of age, first in the foundry and afterward in the machine-shop. No small part of his subsequent success is due to his thorough training in these two fundamental branches of the iron industry.

By fifteen he was earning journeyman's wages. In 1856 we find him at Philadelphia working as a machinist with I. P. Morris & Co., then in Clearfield County, during a commercial depression, as a lumberman and farm hand. In 1859 he is a machinist in the employ of the Cambria Iron Company; three months later he goes to Chattanooga, Tenn., employed by a blast-furnace company, where he remains until 1861, when, by the breaking out of the Civil War, he is forced to flee with his young bride.

A year later he enlists in the 133d Pennsylvania Volunteers, is wounded, but rises to the rank of corporal. At

the expiration of his enlistment he returns to the Cambria Iron Company, but soon raises a company of men and, as their captain, re-enlists in the 194th Pennsylvania Volunteers, and serves to the close of the war. The latter part of the time he was Provost Marshall for the city of Baltimore, a position requiring both tact and firmness, and for which service he received honorable mention.

Then he returns again to Johnstown to be assistant to George Fritz, the chief engineer of the Cambria Iron Company. In this position he is busied in designing and constructing the famous Bessemer plant and bloom-mill, under the direction of two of the most brilliant of American mechanical engineers, Alexander L. Holley and George Fritz.

Following the death of Fritz, Jones resigned from the service of the Cambria Company. So well had he done his work that Holley, who had designed the Edgar Thompson Steel Works at Braddock, selected him to be the master mechanic. Holley was at this time consulting engineer of the Associated Bessemer Manufacturers, and acquainted with all the principal steel men. He looked upon Jones as the best practical administrator among them all.

Later Jones became the general superintendent, and still later, in 1888, consulting engineer to all the Carnegie companies. In these years he erected their great Bessemer plants, the remarkable series of blast furnaces known as A, B, C, D, E, F and G, and the gigantic rolling mills; he met and overcame all the contingencies of daily operation and intense competition that culminated in making these establishments the finest in the world and a transcendent financial success.

A dozen patents stand to his credit and all have to

do with the manufacture of steel. The first was granted in 1876, a device for operating Bessemer ladles, and the last, in 1889, considered to be the most important, a method for mixing in receiving tanks the metal from blast furnaces.

But his fame does not rest upon these few patents. Like all mechanical engineers engaged in the practical administration of affairs, he invented and devised far more than he patented. Invention was to him a necessary incident of daily routine.

These vast concerns are not born full grown. Engineers' plans are never perfect on first presentation. Errors are to be corrected, omissions supplied, interferences adjusted, methods simplified by incessant watchfulness and practical mechanical judgment.

There is also a struggle for existence and a survival of the fittest among steel plants as among animals. A comparison of daily reports, a searching of costs, the stimulus of competition—all compel constant improvement or defeat, and time has shown that Jones was to be trusted to keep the mechanical equipment of the Carnegie plants ahead of all competitors.

Here were thousands of men employed, and the selection and management of men measures, in large degree, the success or failure of any enterprise.

In these things Captain Jones was pre-eminent. Under his control vast forces were co-ordinated, warring elements harmonized, selfish interests dominated, and the whole organization vitalized, until the production of a single blast furnace went up before his death from 350 tons a week in 1872 to nearly 2,800 tons per week.

One of the wires to this Carnegie system was rivalry between heads of departments. Rewards were given

for record outputs, these were made the standard, and woe betide him who fell short.

It was competition, bitter and relentless, engendering strife and hard feeling, and yet none dared to let up on the terrible pace.

Jones was not responsible for this. He was too high spirited to stand it himself, and when his protests were unheeded, he sent in his resignation again and again, only to be won back; he was too valuable a man to lose.

"You can imagine the abounding sense of freedom and relief when I go aboard ship and sail past Sandy Hook," once said Andrew Carnegie to Captain Jones. "My God, think of the relief to us," exclaimed Jones.

When Carnegie offered him a partnership he declined, but accepted "a thundering big salary," \$50,000 a year, when salaries of ten were few and far between.

When Carnegie was taken to task by some of the other steel manufacturers for paying such a salary, he responded that he would be glad to pay double if he knew of any more like him.

Under Jones' management men worked as never before or since. His unerring mechanical judgment, his organizing ability, his unfailing energy, his resistless enthusiasm, won their hearts, and they responded loyally as to a recognized and trusted master.

In his dealings with them Jones was considerate and sympathetic, at the same time forceful and determined. He attempted an eight-hour day at the Edgar Thompson, but when it was shown that it was falling slightly behind the others, it was vetoed.

When called upon to resist extreme demands his opposition was open and above board, so that even in

the very fiercest of the conflict he retained the good will of his opponents.

It was characteristic of him, at the time of the Johnstown flood, to take several hundred workmen from Braddock by special train. The track was destroyed ten miles from Johnstown, but Jones marched the men overland, and was the first outside assistance to reach the scene of destruction. Under his trained direction, they rendered invaluable service in the work of rescue and relief.

He was a member of the American Institute of Mining Engineers, and, although the leading iron and steel expert of the country, persistently refused to accept office or read papers. He was also a member of the American Society of Mechanical Engineers, and of the British Iron and Steel Institute.

He was a man of considerable property, of stalwart figure, and attractive face. His striking portrait shows a remarkable likeness to that of the greatest of Roman commanders, Julius Caesar, save only the eyes, which belonged to Jones alone, keen, alert, laughing and honest, characteristic of the real man.

His tragic death was a striking close to such a life. Blast furnace C had been in trouble for several days. The regular organization was unable to bring it under control. Captain Jones assumed personal charge of affairs, and while directing the work an explosion occurred in the furnace which caused a rush of gas and molten cinder to fly in all directions. Several men were badly injured, and he was not only horribly burned, but was blown against an iron cinder car, fracturing his skull. He suffered intense agony for two days, and died September 28, 1889.

In the resolutions offered by the managers of the Carnegie properties, it was said:

Jones.

"We would not forget that the commander fell at the head of his men, at the post of duty, amid the roar of the vast establishment which was his work and is his monument."

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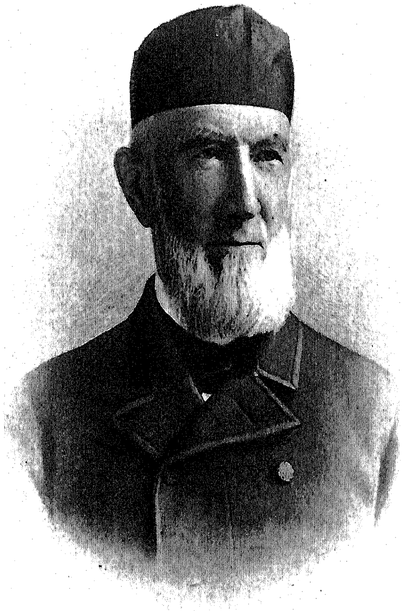

James B. Eads

1820-1887

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James B. Eads.

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In these days of gigantic enterprises, canals, bridges, tunnels and harbor improvements, it is strange that we hear nothing of ship railways, and yet that was the proposal in his mature years of one who was a master of construction, but who died before it could be realized.

James B. Eads was an engineer who left behind him colossal works of immense usefulness to his country. His father and mother were both of the more refined classes of our great American cosmopolitanism, he from Maryland, she of Irish blood. The father, however, while not poor, was far from prosperous, and moved first to Cincinnati, and then to Louisville, and then to St. Louis.

James was born in Lawrenceburg, Indiana, in 1820. He was nine years old when they floated down the Ohio to Louisville. It is reported that at this early age he was intensely interested in machinery, listening carefully to the engineer's explanation of his engine, and remembering so clearly that when only eleven years old he made, in a little workshop his father fitted up for him, a complete little engine. Besides this he made models of sawmills, steamboats, and other machinery that came to his notice. He had slight education, but a fondness for reading that grew in him with the years.

When he was thirteen, his father decided to move to St. Louis, and sent his wife, two daughters and James

on ahead, intending to follow with supplies for opening a shop. The boat on which they went caught fire one cold morning, and the passengers were landed scarcely clothed and with no baggage, on the very spot, it is said, where, years later, Eads was to plant one pier of his great bridge. But Mrs. Eads was not one to be discouraged. She immediately opened a boarding-house, and James did his best selling apples on the street and running errands. One of the boarders was a dry goods merchant, who, seeing the boy's industry, set him at work as a clerk, and permitted him the free use of his library. From these books he gained his first theoretic knowledge of science when nineteen. After five years of this indoor life, his health failing, he left it to be a clerk aboard a Mississippi steamer.

From this time on his life was intimately connected with this great river. He came to know and understand it as none other ever did. Its vast flood unceasingly rolling on to the sea; eating away its banks on one side only to pile up the sediment on the other, making bars in a night; eating its way through a bend to pour in torrents through a new channel that leaves the old miles away; uprooting giant cottonwood trees and depositing them in the open channels, a menace to the shipping and anchorage for a new bar. With all the skill of a race of born pilots, steamers and flat-boats were everywhere wrecked and left with their valuable machinery and cargoes.

After three years as clerk, in 1842, when twenty-two, Eads went into business with a firm of boat-builders, his part being to raise these sunken boats.

His first contract was to raise a barge-load of pig lead sunk 212 miles from St. Louis. A hired professional diver refused to descend when he saw the swift current,

and so Eads himself went down in an improvised diving-bell, made out of a whiskey hogshead. For three years he kept at it and devised many arrangements to facilitate his work. He built powerful wrecking-boats, fitted with great pumps to draw out the sand, and derricks that would lift the barges by main force from the bottom.

It was a harzardous business, but his energy and cleverness and boldness made a success of it. He used to say that there was not a stretch of fifty miles from Galena to the mouth but where he had walked on the river bottom.

He gave it up to marry, and went into the manufacture of glass—the first factory west of Pittsburgh, but in two years it failed in spite of his extraordinary energy, and left him $25,000 in debt.

Then he rejoined his former partners in the wrecking business, and worked harder than ever. In ten years his debts were paid and his firm was worth a half million dollars. He began to give attention to the obstructions of the current, and took contracts to clear the channel and improve harbors.

In 1856 he went to Washington and offered to contract with the government to clear the channels of the Mississippi, Missouri, Ohio and Arkansas rivers, and to keep them clear for a term of years. The bill passed the House, but was defeated in the Senate.

In 1857, when thirty-seven years old, he retired from business and made his first trip to Europe. At the breaking out of the Rebellion, four years later, Eads at once took a prominent part in Missouri and national affairs.

When the question of the control of the Mississippi came up, Eads was the man of the hour. Lincoln called it the "key to the whole situation." At the request of the

government Eads prepared a statement of his views and plans that were adopted by the Navy Department, but the War Department claimed jurisdiction, and subordinated Eads to an officer. At first Eads' suggestions were overruled, and in July, 1861, bids were asked for the construction of seven iron-clad river boats. Eads' bid was lowest in price, and quickest in time. Eads agreed to deliver the boats in sixty-four days. It was a time of turmoil and financial distress; mills were idle, and skilled labor scarce. Eads, with his intense energy and considerable wealth, threw himself into the work. Machine shops and foundries were set to work, timber was brought from eight different states, telegraph wires to Pittsburgh and Cincinnati were kept busy for hours. The first iron plating used in war was ordered to be rolled in three states; in two weeks 4,000 men were at work on these boats, miles apart, day and night, seven days a week.

But as usual the government delayed the work by altering the plans, demanding better work than originally intended, and delaying payments. The boats were not built within the sixty days, but were launched within a hundred days, and engaged in battle before being paid for. Eads began them a rich man, but was financially involved before they were finished, and Congress had appropriated their cost. These boats were 175 feet long and 51½ feet beam, practically flat-bottom scows, protected on four sides by heavy oak planking slanting up and in. The front was also iron-clad. These were the first iron-clads ever in actual battle. They were very faulty in design, but did excellent work all through the war. Before they were completed Eads was authorized to construct another boat after his own designs for Gen-

eral Fremont. This was of twice the tonnage and more completely iron-clad.

In 1862 Eads was authorized to build two turreted iron gunboats, and later the order was increased to six. As this was immediately after the battle of the Monitor and Merrimac the government insisted on using the double Ericsson turrets on four, but permitted Eads to use his own design of a single turret with guns worked by steam on two, on his guarantee to replace them, if unsatisfactory, with Ericsson turrets at his own expense. These proved successful and were fired seven times faster than the Ericsson guns. Besides these fourteen boats, Eads converted seven transports and built four mortar boats. Captain Mahan speaks of these boats built by Captain Eads as the "backbone of the river fleet throughout the war."

At this time Captain Eads was the most important citizen of St. Louis. He had a beautiful residence outside the city, and entertained lavishly. He was a very busy man, now at his ship-yards, now at Washington, now at the front watching his boats in action. He made many inventions—new guns, and carriages, new methods of operating turrets, applying steam to artillery, etc. He introduced his inventions not only at Washington, but to the German and Russian governments. He was appointed special agent of the Navy Department to visit European navy yards. But this strenuous life told on him, and before the close of the war he had a serious collapse.

After the war he traveled in Europe extensively, and in 1867 made an important address before a convention assembled at St. Louis to consider Mississippi river improvements, and the same year a St. Louis company, of which Eads was chief engineer, was authorized to con-

struct a bridge over the Mississippi, with the almost unheard-of spans of 500 feet—fifty feet clear above the river. Eads' plans were severely criticised, but generally as being unnecessarily strong. His plans called for two river piers of heavy masonry built up from rock foundation. One of these was 110 feet below the surface of the river, 90 feet of which was through mud and sand. To sink these massive piers Eads' genius manifested itself. It was the deepest submarine work that had ever been done, and called for the highest engineering skill. From his fertile mind came designs of air-tight metal caissons, sand-pumps, air-locks and conveyors. The superstructure consisted of three steel arches, by far the largest ever constructed up to that time. Two were 502 feet long, and one 520 feet. They were built out from the piers and met at the centre without staging below. The bridge was seven years in building, and stands to-day a monument to its builder, establishing his standing as an engineer above dispute.

The next field for his talents was the question of an open channel to the Gulf. Eighteen feet was the deepest channel ever obtained up to 1875, and this was only intermittent; a severe storm from the Gulf or high water from the river would undo in a single night the work of months of dredging and stirring. Jetties had been proposed years before, but were generally condemned as "difficult to build, impossible to maintain, and excessively costly."

In 1875 Eads came forward with an offer to construct jetties on one of the passes, to secure and maintain a twenty-eight-foot channel at a cost of less than one half the estimate of government engineers, on a contract which provided payment only in case of success.

To hand over the most important engineering work ever undertaken by the government to a private citizen, after a method just condemned by six out of seven of her ablest military engineers, made Congress hesitate. But the open channel was highly desirable, and Eads was finally given permission to construct his jetties on one of the smaller passes—to secure and maintain for twenty years a depth of twenty-eight feet. The small pass was far more difficult than the larger one that Eads desired, and twenty years was a long time to wait for pay, but Eads went at it with his usual energy.

First of all, the work was to be financed with the outcome problematic and dividends twenty years away. Then the work was planned, organized and pushed. After all his plan was simple and successful. It was based on his belief that the amount of sediment a current would carry was directly proportionate to its velocity, so he narrowed the channel by jetties and the river scoured its own channel.

But there were many difficulties, and Eads, as usual, made many devices and arrangements to further his work. The opposition and derision continued until one day an Atlantic liner appeared at the New Orleans docks and the jetties were saved.

In 1879, a little over four years after they were begun, government inspectors reported a maximum depth of thirty-one feet and minimum of twenty-eight of the required width. Eads was promptly paid all except $1,000,000, retained as a guarantee for their maintenance.

The work has been wonderfully successful, and plainly increased the value of the whole Mississippi valley, and raised New Orleans from the eleventh to the second export city of the nation.

But this did not end his activity; he at once set about urging the national government to apply the same principals to the entire alluvial basin. He served on the Mississippi River Commission, but the plan proposed by him was too vast and costly to be adopted, and after two years he resigned.

He was now sixty years old, and an authority on harbor and river improvements. He traveled much and gave much professional advice, notably as to St. Johns, Columbia and Sacramento rivers, and the harbors of Toronto, Vera Cruz, Tampico and Vicksburg. He also declined very flattering offers from Brazil, Turkey and Portugal. His two most important reports were on the estuary of the Mersey at Liverpool and Galveston Harbor.

The publication of the De Lesseps Interoceanic Canal Plans in 1879 gave Eads his opportunity to propose the famous ship railway across the isthmus at Tehuantepec. It consisted of a cradle big enough to float the largest ship resting on 1,500 wheels on a dozen parallel rails. His route was 2,000 miles shorter than the Panama and, according to his calculations, cheap, quickly built, safe and rapid, easily maintained and increased.

The plan was declared feasible by a large array of engineers, but was ahead of the times and lapsed with his death. He gave six years of his ripest powers to this enterprise, and gave it up only with his life in 1887.

In 1884 he received his highest honor, the Albert medal. He belonged to many societies in the United States and England.

He was an engineer of extreme boldness and energy, self-educated, largely and exceedingly practical in all his ventures, and eminently successful as a business pro-

moter. In person he was slight, but dignified and impressive. He was notably punctilious in dress and behavior, which, together with his masterly powers of conversation, persuasion and explanation, gave him remarkable influence over men.

While rather severe in manner he was genial at heart, loved stories, hospitality, good books and chess. The latter game he could play blindfolded, or carry on three games at once. He was typical of the West, self-made, self-confident, bold and courageous, with enthusiastic energy that was almost inexhaustible.

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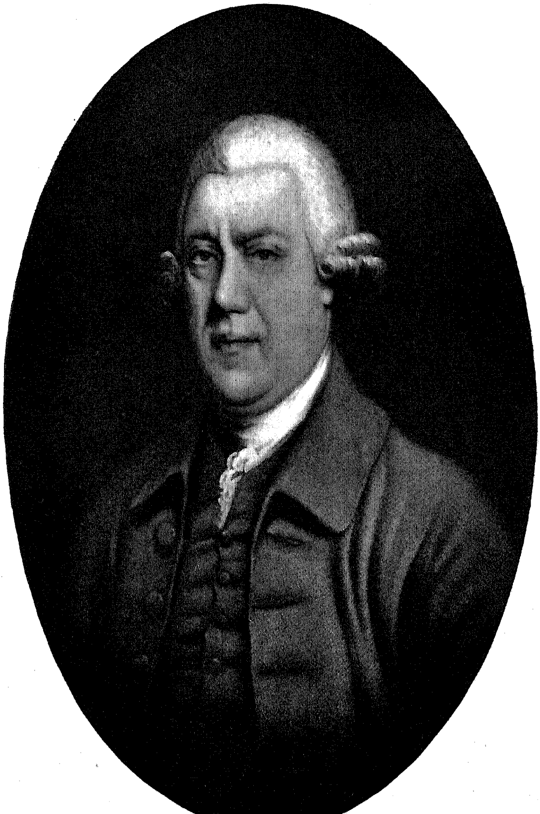

Sir Richard Arkwright

1722-1792

Richard Arkwright.

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It is a long cry from Dick Arkwright, the ignorant, impecunious barber, to Sir Richard Arkwright, the millionaire manufacturer, but they are one and the same.

He was born in 1732, in Lancashire, at a time when the social condition of English labor was at lowest ebb.

He is interesting to us, especially because to his genius the world is indebted not only for the first cotton power machinery, which was the very beginning of power machinery of any kind, but also for that elaborate organization that made modern factory manufacture and business administration so great a success as to entirely supersede in the course of years the primitive cottage production and sale.

He was a long time getting a start. In the first place his parents were poor and he was the youngest of thirteen children. He seems to have given up shaving in 1760, when nearly thirty years of age, to travel about buying and selling hair. At about the same time he secured a secret process for dyeing hair that gave him a monopoly of the best business.

Having once tasted the sweets of success from the possession of manufacturing secrets, patent rights and monopolies, he went on from one thing to another, unremittingly, to the time of his death.

First he dabbled in perpetual motion, and in trying

to find a mechanic who could make some wheels, became acquainted with a clock-maker named Kay, who had worked with Hargreaves, the inventor of the spinning jenny, and one Hayes, the inventor of some sort of a spinning arrangement.

This connection turned his thoughts toward cotton manufacture, and was the indirect cause of much subsequent trouble and vexatious litigation. His enemies claimed that his ideas were not original, but were stolen from Hargreaves and Hayes and therefore not patentable, but Arkwright claimed originality and the courts in the end sustained him. The whole story of his subsequent inventions, incessant mental activity and tremendous energy certainly endorses his claim.

Before his day, cotton was wholly spun by girls and women in their homes, at starvation wages and in unsatisfactory quantities.

Arkwright's invention was to draw the cotton through a double pair of rolls, the second of which revolved faster than the first and to do it by water power.

It increased the output enormously, from one spinner and one thread to one spinner and a score of threads, at greatly increased speed.

A second gain of even more value was made, for by this arrangement the thread could be twisted hard and fine enough to serve also for warp, where before only wool and linen had been used.

So great was the economy of this and other of Arkwright's inventions that what one man and four children could now spin, before had required 600 women and girls. This invention was the very foundation of the world's gigantic cotton industry.

Of course other men had been at work on this same

problem with varying success, and when its worth was established contested bitterly his claims to priority and forced him to defend his rights against general infringement.

Arkwright had to meet these difficulties and also the dangers that followed from the anger and fears of the down-trodden laborers, whose calling was threatened and who did again and again riotously destroy every trace of the new machines, lest their condition be made still worse.

But his extraordinary intellect and will once aroused, he plunged with amazing ardor into the perfecting of his machinery, the defense of his patents, the construction of factories of unprecedented size and the general business administration of his multitudinous affairs.

In 1767 he obtained his first patent. In 1771 he erected his first mill. Then follows a series of improvements in carding, roving and spinning that were so complicated, various, and yet so admirably adapted to the end in view, as to excite admiration.

Although unused to business, he systematized his affairs and arranged his works so wisely that the main features remain unaltered to the present. His energy was phenomenal. He worked incessantly from five in the morning until nine at night. If obliged to go from place to place, he traveled with four horses at full speed so as not to be delayed. He even separated from his wife, that home demands need not interfere with business.

After he became conscious of his lack of education, and even late in life, he continued to give an hour a day to the study of grammar, and another hour to improve his writing, when others would have been asleep.

After 1776 profits began to be realized, and from

then on wealth flowed in abundantly. He was made High Sheriff in 1786, and knighted by George III at considerable cost to himself.

He was naturally very strong physically, but during the last years of his life suffered severely from asthma. He died at home in 1792, aged sixty years, worth over a million dollars, an immense wealth for those days.

His most marked traits were energy, industry and perseverance.

These traits combined to give him an astonishing power of transacting business, and raised the ignorant barber from poverty to rank and affluence.

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Thomas Newcomen.

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Concerning the personal history of this engineer very little is known and yet the engine which bears his name was the very first use of steam in a successful steam engine. It was so successful that it held the field almost without dispute for the half century preceding the epoch making inventions by James Watt.

There is no record of his birth, but the house in which he lived was standing until comparatively recent years, on Lower street, Dartmouth. It was apparently a house of the better class and there are numerous indications of his respectable standing and connections. The parish church contains a group of memorials of his near relatives which all bear the mark of comparative wealth, but nothing remains to indicate the days of Thomas.

Smiles follows the removal of the family northward but there the traces disappear completely.

He was a blacksmith and ironmonger by trade and as such had a high standing for excellent workmanship. It happened that Capt. Savery, the inventor of the vacuum pump, lived at Modbury which was only fifteen miles distant. He made a great many experiments and in one place it is recorded that he complained of the difficulty he had in getting machinist labor of sufficient skill to do his work. This gives color to one story of the beginning of Newcomen's interest in the use of steam which is that

Savery had him do more or less of his work. At any rate the experiments of Capt. Savery were common knowledge and must have been known by such a skilled workman as we know Newcomen to have been, and who lived only fifteen miles distant. We also know that Newcomen had drawings of Savery's pump and set one up in his garden with which to experiment, but Switzer, who was a friend of Savery, says that although Savery received in 1705 the first patent for the use of steam, (it is interesting to know that this is also the first recorded patent of any kind) that Newcomen was fully as early in his experimental work and failed in securing priority because of Savery's more intimate relations with the government. The Newcomen patent was granted in 1707 to three associates, Newcomen, Cawley and Savery. There is no doubt that Newcomen was the real inventor. Cawley was a glazier who was his assistant and Savery was included, it is generally accepted, because of his strenuous insistance that any use of the condensation of steam was an infringement of his 1705 patent. The true facts are that Newcomen's invention was radically different from that of Savery or any other single person. Papin invented the cylinder and piston as a means for transforming energy into motion. At first he used the explosive force of gunpowder, and later the use of the expansive force of steam to raise the piston, and then by removing the fire to cause it to fall again. He made no further use of this principle. Savery discovered that the sudden condensation of steam made a vacuum that he utilized to draw up water. His pumps were actually used to drain mines but were never satisfactory. They had to be placed within the mine to be drained, not over forty feet from the bottom and then could be used to force up water an additional height of

perhaps 100 feet. Beyond this the process must be repeated. It will be noticed that the water to be forced came into direct contact with the steam which was contained in a solid vessel.

In addition tremendous pressures were necessary, as high as twelve hundred pounds per square inch were secured and with the materials for construction at hand frequent and disastrous explosions were the result.

Newcomen used Papin's cylinder and piston, and Savery's principle of the condensation of steam to produce a vacuum. But unlike Papin he used the expansive force of steam to do this work and unlike Savery he used a cylinder and piston actuated by alternate expansion and condensation of steam to transform heat into mechanical motion.

Thus it is seen that Newcomen like a good engineer constructed his machine from the suggestions of his predecessors. At first he made a double cylinder using the space between for condensing water. This was not very satisfactory. The vacuum was secured very slowly and imperfectly. In 1711 they attempted to erect an engine for draining a mine but failed. The next year they succeeded in erecting it but it was slow and ineffective. To operate it required two men and a boy. The boy's work was to alternately open and close the valves to the condensing water and to the boiler. One day the engine made two or three motions quickly and powerfully. Newcomen immediately examined the cylinder and found a small hole, through which a small jet from the water that was on top of the piston to make it steam tight, was spurting into the cylinder. He appreciated the significance of the incident at once, dispensed with the outer water jacket and injected the water for condensation,

through a small pipe in the bottom of the cylinder. It was a success at once and increased the speed of the engine from eight to fifteen strokes a minute, besides getting the advantage of a good vacuum.

In 1713 a pump was erected in Leeds and the boy who was hired to open and shut the valves, in an effort to make his work easier, rigged up a contrivance of strings and levers that operated the valves from the motion of the working beam overhead. This made the engine automatic and marked another stage in its evolution.

This boy, Humphrey Potter, afterwards became a good workman and was sent to Hungary to erect the first engine set up there. This valve motion was afterward improved by Henry Beighton in 1718.

This engine as it was now constructed and remained to be until the days of Watt consisted of an underground furnace, over which was placed a semi-spherical boiler the flat side of which had a deep spiral groove along which the flame and heat passed to the chimney in which at first was no damper even. Immediately above the furnace was the cylinder, braced in place by the timbers of the building. About twelve to thirty feet above was the cistern for condensing water from which descended a pipe to the bottom of the cylinder. Another pipe carried the water of condensation to the hot well. Henry Beighton also used this water for boiler supply. High above was the huge wooden working beam pivoted on the wall of the building. The piston was suspended from the beam by a chain that was kept central by winding on an arc on the end of the working beam. From this beam also came the rod and pegs for operating the valves. From the other end of the working beam outside the engine house and directly over the pit mouth was at first another

chain, connecting to a single acting solid pump plunger. At first the boiler bottoms were made of copper and the tops of lead. Later on sheet iron was used, but not until 1743 was cast-iron used for this purpose. The steam space was eight or ten times the cylinder capacity. The third engine to be erected was at Ansthorp. It had a 23-inch cylinder, 15-inch stroke, 9-inch water plunger, and raised the water in two lifts of 37 yards each. For this Newcomen was to receive $1,250 a year for which he was to operate and keep it in repair. In the years that followed the size of these engines increased until Smeaton erected some with cylinders of six feet in diameter. By the aid of these engines the mines could be sunk to twice the depth possible before, but the expense was very great, involving in one case $15,000 a year for coal for the engine.

It was a model of one of these engines that came into the hands of James Watt for repairs that set his mind at work upon the problem and resulted in the modern high pressure reciprocating engine.

Newcomen himself was a man of very great modesty and worth. He was very religious and was accustomed to preach in Baptist chapels wherever Sunday found him.

No record of his death is known, but it is supposed that with the increase of the vexations of business competition he retired northward to private life and died about 1750.

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James Watt
1736-1819

This cut was made from a bas relief, drawn up by hammering from a sheet of bronze. It is framed in old English oak. Found in a junk shop in New York.

James Watt.

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The name of James Watt, the inventor of the steam engine, is familiar to all, but even if the name is well known his great learning and various accomplishments are seldom appreciated.

The lines of his genius run back to very worthy ancestors. His grandfather was a teacher of mathematics, a magistrate and a church elder. His only uncle was a surveyor; his father a magistrate, town treasurer, shipwright and merchant; his mother a superior woman of the Clan Muirheid.

James, the great engineer, was born at Greenoch, 1736. His health was very delicate as a child, and he grew up "a mother's boy." Frequent headaches prevented his regular attendance at school and even to the day of his death interfered with his work, but in spite of almost overwhelming obstacles, he kept steadily at his researches and continually added to his attainments. Even as a lad he was remarked for his studious ways—and the incident is well attested of his aunt scolding him for sitting idly by the fire watching the steam from the kettle condense on the inside of a cup.

When only fifteen he had studied natural philosophy, anatomy and made many experiments in chemistry and electricity. He was interested also in his father's shop, became quite skillful with tools—and made and repaired

some of the instruments his father sold to ships. In this way he became acquainted with astronomical instruments, telescope and quadrant—and these led him to the study of astronomy. When eighteen he went to Glasgow, apprenticed to a mathematical instrument maker, and there, through an uncle, who was a professor, became acquainted with a number of college professors. Later he goes to London for better instruction in the art of making instruments. When twenty, in 1756, he was a skilled artisan and returned to Glasgow and set up a shop of his own. In a short time he had some troubles with his trade guild and his friends among the college professors made a place for him within the college grounds, ostensibly in order to make repairs on college apparatus.

This was a very congenial place to him. He was in daily contact with the best educated men of the day—busied with the instruments and apparatus for advanced research. All this time he was studying and acquiring a broad scientific knowledge and he was soon looked up to even by the elder professors as an authority in scientific matters. It was during this time that his thoughts were turned particularly to the use of steam for mechanical purposes. Many a man before him had dreamed and experimented and died in poverty and discouragement, to blaze a way toward possible success.

The French engineer, de Caus, who lived in England about 1612, seems to have been the first to notice that heat applied to water in a containing vessel would, if a perpendicular tube was inserted nearly to the bottom of the vessel, elevate the water in it and, if the heat was great enough, expel the water through the tube.

Forty years later the Marquis of Worcester noted a "water commander" as one of the hundred inventions

that he had "perfected." He used steam to lift water to a height. But after loaning above a half million dollars to his forgetful King, he was forced to die in poverty, avoided as an importunate visionary.

It was twenty years later in 1683, that Sir Samuel Morland proposed a method for using steam as a mechanical force, but his method appears to have been a repetition of de Caus' experiment. He is the first, however, that determined the volume of steam to be 2,000 times that of water. Thus far the pressure of steam was only used directly against the surface of water to propel a jet of water. In 1690 Papin, another French engineer living in England, made a distinctly new proposal, namely the insertion of a piston in the vertical tube, for the transfer of the motion to a more convenient mechanism. Papin was trying to perfect a lifting machine and only used steam to produce a vacuum, which he secured by alternately placing and withdrawing the fire under the cylinder. He made no use of this invention himself, but left to those who came after the knowledge of two new principles—the use of the condensibility of steam by simple exposure to cold, as a moving force and a method for communicating the moving force of steam to bodies upon which it could not act directly.

The next advance was made by Captain Savery in 1698. It is said that he noticed one day, when he accidentally immersed his heated pipe in cold water, that the water immediately rose up into the tube. He applied this principle to raising water from a depth and thus had the first suction steam pump. He produced his vacuum by dashing cold water over the heated cylinder.

Captain Savery was a man of great ingenuity and

made many improvements in his pump, but it was never a great success.

In 1718 Dr. Desaguliers contrived a method for condensing the steam of a Savery pump, by injecting a small stream of cold water into the vessel. At about this same time Thomas Newcomen invented the engine that bears his name. He used Papin's principle of a steam-produced vacuum under a piston, but improved upon it by condensing his steam with injected cold water as proposed by Desaguliers. This atmospheric engine was found to be immediately useful in pumping out deep mines and other purposes but proved to be very costly in operation.

It was a model of this engine that came into the hands of Watt for repairs in 1763, that set his keen wits at work for its improvement. It was quite characteristic of Watt that in undertaking the repair of this crude model, he first made a careful study of the properties of steam. His pains were rewarded by several valuable discoveries and the first accurate determination of the action of heat on water under pressure. He came to the conclusion that the Newcomen engine had one prime defect, the necessity of cooling the cylinder at every stroke in order to condense the steam. This he avoided by making the condenser separate from the cylinder. It was a success from the start and by leaving his cylinder continuously at 212 degrees, he not only saved three-quarters of the fuel necessary to operate, but the power was decidedly increased by reason of the more perfect vacuum produced.

In trying to make his piston tight enough to keep out air and at the same time not impede its motion, Watt was led to his second great invention. You will recall that Newcomen made no use of the expansive force of steam.

Watt substituted for the atmospheric pressure upon the piston, a second supply of steam and used above as well as below alternate steam and vacuum. By this contrivance Watt for the first time made use of the expansive force of steam as a prime mechanical power and overcame a second radical defect of previous engines.

These are the main grounds upon which rest the fame of Watt as the inventor of the modern steam engine, but the improvements in detail of his finally perfected engine show equally the high qualities of a great engineer. The manner in which this kindly inventor was enabled to make a commercial success of this invention is another story and is more closely connected with the life of Matthew Boulton, which follows. His inexhaustible ingenuity is seen also in the multitude of contrivances apart from those in connection with the steam engine.

He was called upon to repair an organ which led him to a study of the theory of music—and certain of his discoveries as to the nature of musical vibrations proved to be correct—and made the instruments manufactured by him, organs, violins, flutes, to be of exceptional value. One organ made by him cost $10,000. He invented a machine for drawing in perspective.

In 1769 he was employed by the magistrates of Glasgow to survey and construct a canal nine miles long to provide easy access to neighboring coal fields. In this he proved himself to be an excellent engineer but poor business administrator. In the years that followed he was engaged in many important engineering projects, bridge-building, harbor improvements and canals.

In 1770 he suggested a spiral propeller for moving canal boats. In 1772 he had invented a time piece, and a micrometer. 1774 brought forth improved quadrant and

other surveying instruments. 1784 a steam tilt hammer was invented, a locomotive engine, and a little later a smoke consuming device. From this on his prolific inventiveness was more and more devoted to improving the steam engine. These two years were simply filled with various inventions and discoveries, especial mention being made of his research into the composition of water. Independently of his great attainments in mechanics, Mr. Watt was a wonderful man. He was a man of tireless zeal and application and to every problem he brought the same discriminating judgment and amazing resources. Probably no man of his time possessed so much, so varied, and such exact information. His knowledge was not at all limited to science, but covered all branches. He was equally learned in metaphysics, medicine, architecture, music, law and most of the modern languages. His remarkable quickness of apprehension, his unfailing memory and "a certain rectifying and methodizing power of understanding" enabled him to hold at command the widest information. In his extraordinary mind every conception was at once condensed into its simplest form and arranged in its proper place for immediate use. Personally he was shy and reserved, but warm-hearted and easily affected. He was greatly honored by the most illustrious of his contemporaries. He was a Fellow of the Royal Society, a Doctor of Laws and one of only eight foreign members of the French Institute. He died in 1819, aged 84 years.

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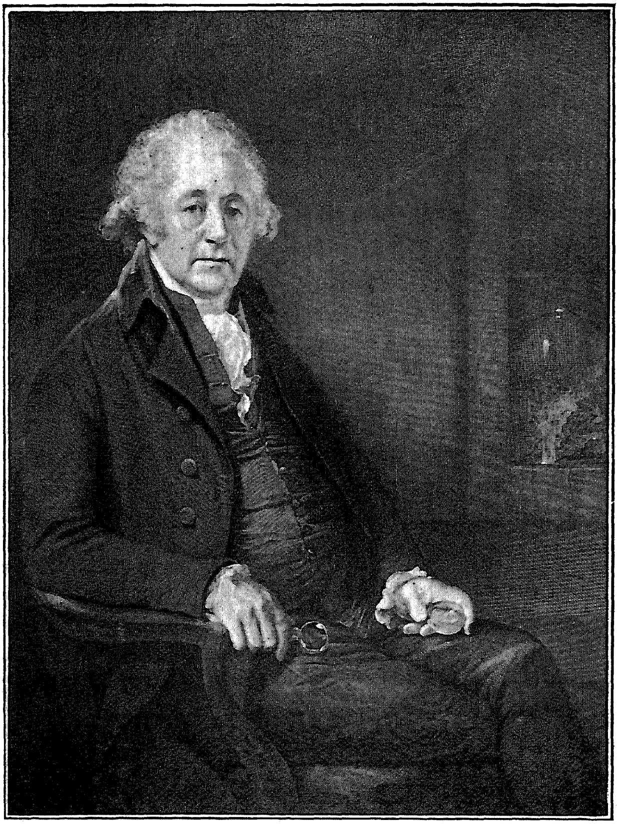

Matthew Boulton

1728-1809

This cut was made from a fine wood engraving (13½ by 16½) by William Sharp, London, 1801, from a painting by Sir William Beachley

Matthew Boulton.

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Matthew Boulton was born in Birmingham, Eng., in 1728. His father was a successful manufacturer of artistic metal work. After a fairly good education young Boulton was taken into the firm when only twenty-one and so capable was he that in a very few years the entire management was given up to him. Discovering a new method for inlaying steel, he built up an enormous industry at Soho. It was the largest shop of its kind in the world, employing above eight hundred workmen with sales of as high as $200,000 per year.

They manufactured all manner of artistic iron, steel, brass and silver work together with scientific instruments and general hardware. Besides employing workers in metals, he had those who could work in tortoise shell, gems, glass, enamel and marble. He employed the very best artists for his designs and the most skilled artisans he could find. His agents were in every great city of the continent and from his works went the artistic adornments of the most splendid palaces of Europe.

As an illustration of the nicety of his art, it is said that he exhibited at a fair in France, a needle perfect in shape and finish, which, when the head was unscrewed, revealed within an equally perfect needle and within that another and another, until a half dozen exquisite needles were found to be neatly packed each within the size larger

than itself. In whatever he did he determined to do better work than was done anywhere else in the world and, keen as he was for commercial success, he was far more interested in the real worth and the artistic excellence of his product.

In 1767 Boulton had constructed at the great Soho works a steam pump after the plans of Savery and had thus become interested in the problem of steam, and hearing of Watt's improvement entered into correspondence with him. Mr. Watt not having any money of his own with which to develop his inventions, entered into partnership with Dr. Roebuck, an extensive speculator in iron works and coal mines, but whose many venures kept him in a chronic state of financial uncertainty, so that after eight years of dissatisfaction it was dissolved and another arranged between Boulton and Watt.

The same year, 1775, that saw the beginning of the American Revolution, saw also the beginning of the manufacturing of steam engines by the new firm at the great Soho works. They obtained an extension of twenty-five years to the life of their patent and began at once an energetic effort to introduce their engine. They first built a pumping engine with a cylinder of twelve inches and set it up at Soho. This they exhibited to visitors and offered to set one up anywhere free of expense, for one third of the saving in coal over the common Newcomen type. As three-fourths of all the coal burned was wasted in the old engines their profits theoretically would have been enormous.

This first engine proved to be, however, but the beginning of many troubles. Already Watt had given eight years' thought to it and it was six years since the

patent of 1769 was granted. Their first troubles had to do with the mechanical difficulties of manufacture. There were no tools capable of machining such large work. Smeaton, the best mechanic of the day, doubted, on this ground alone, the success of the steam engine. It was a real difficulty, because the success of a reciprocating steam engine is measured by the relative absence of friction, which is conditioned by the precision of manufacturer. Little by little, however, special tools were invented and, what was of most importance, a school of machinists were educated who were capable of working to the required standard.

A second class of troubles had to do with the collections of royalties for the use of the new engines. Most of the earlier ones were set up at the mines in Cornwall and never paid anywhere near the agreed amount. The oversight of these engines and the collection of the dues devolved in large part upon Mr. Watt, to whom it was extremely distasteful. When he became thoroughly discouraged, Mr. Boulton with his tactful address would go and straighten the matter out. There were continuous law suits over collections and patent rights until 1799. Mr. Boulton's affairs, apart from the engine industry, became involved also and absorbed much of the profits of the engine building. But in spite of these discouraging circumstances both Boulton and Watt continually improved the engine, patenting successively various axial motions, governors, throttles and devices for using steam expansively.

Little by little they won out, not only in the engine industry but also along other lines. Their mutual improvements in coinage and coining machinery were espe-

cially successful and brought them immense business, not only in England but in all Europe.

These two men perfectly supplemented each other. Watt was a consummate engineer, of faultless judgment and unlimited resources, but so shy and easily discouraged that he was utterly unfitted to introduce and make a commercial success of his inventions.

On the contrary, while Boulton was a rare craftsman himself, he was preëminently a commercial organizer and promoter. He was a man of exceedingly attractive presence and of fascinating address, which, together with his wealth and education, placed him on terms of intimacy with kings and nobles all over Europe.

Boulton died in 1809, aged eighty-one. Watt lived two years longer, and the firm was continued for years after by their sons.

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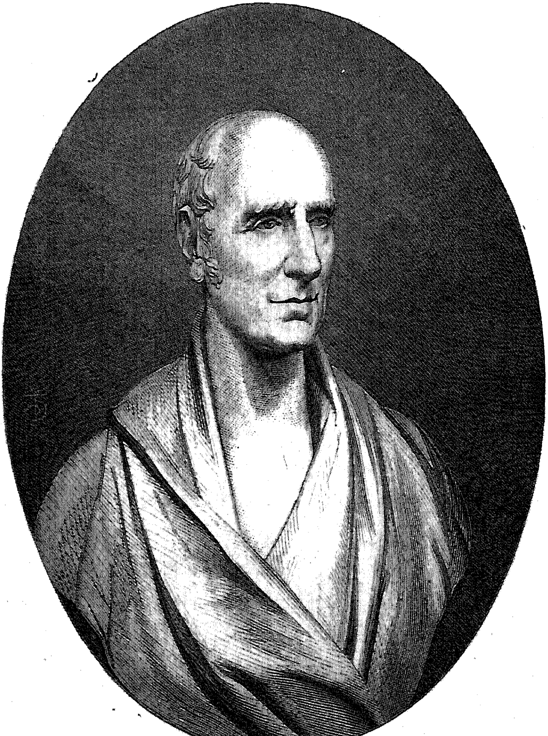

William Murdock

1754-1839

William Murdock.

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William Murdock was for fifty years the mechanical expert for Boulton and Watt in the development and introduction of the steam engine. His father was a miller and millwright of Bellow Mills, near old Cumnock, Ayrshire, Scotland, and was highly esteemed for his uprightness and mechanical skill.

His son, in after years, loved to show, resting on a pillar on his lawn, an old cast-iron bevel gear that his father had made. The inscription upon it was as follows: "This pinion was cast at Carron Iron Works by J. Murdock of Bellow Mills, Ayrshire, 1760, being the first tooth gearing ever used in mill work in Great Britain."

William was born in 1754 and early showed a marked bent for mechanical pursuits. He had little schooling and secured his by no means ordinary intellectual equipment by close and patient effort.

In 1776 he offered himself to Boulton and Watts as a mechanic. He was a big, overgrown country boy with nothing to commend himself. Watt was away, and Boulton with no interest was sending him away, when he noticed a curious looking hat in his hand. He asked him of what it was made. The reply was, "Of timmer wood. I turned it mysel', sir, on a bit lathey of my own making." This curiosity so aroused the interest of Mr. Boulton that

he hired Murdock on the spot for fifteen shillings a week at the shop, seventeen when away, and eighteen when in London.

For fifty years he stayed with the firm and became their most trusted adviser in all mechanical undertakings of any importance.

He was incessantly busy contriving, inventing and improving the product of the firm. The greatest of all the early difficulties of Boulton and Watt was with the Cornish mining captains. Watt spent much time there, but without Murdock he never would have succeeded. Murdock worked night and day overcoming the mechanical difficulties. Once when an expensive engine had been installed it failed to work after a little, and the angry miners started to mob Murdock. He was a giant in size and strength. He forced his way among them, went at the engine again and removed the difficulty. Then they carried him on their shoulders in gratitude instead of mobbing him. But greater than the mechanical difficulties was the unwillingness of the mining captains to pay the agreed royalty. They tried to corrupt Murdock, and it took all the resources of his genius to maintain the rights of his principals. On one occasion, at Chacewater, it is said, when a company wanted him to meet them and offered him bribes to betray his firm, he shut the door and actually thrashed them. He did his best to the end, and only left when his life was seriously threatened. His zeal at Cornwall quite won Watt's heart. Boulton wanted to send Murdock away to erect engines to Scotland and the continent, but Watt would not listen to it. Murdock was the only man he could trust at the factory. If any work required particular attention, Watt always directed that "William" should do it.

Until 1780 he only received twenty shillings a week. Then he asked for an increase, and Boulton shrewdly satisfied him with a present partly from the Cornish miners and partly from himself. Although he received no other advance at that time, he remained faithful. Even when tempted with a partnership, he refused to leave his old friends. In later years they treated him more generously, and although he never became a full partner, he was counted the chief mechanical superintendent and adviser. After 1810 he received $1000 a year in lieu of a share in the profits.

He was a very skillful craftsman, besides being quick-sighted and indefatigable. If Watt wanted an idea of his put into mechanical shape, no one but "William" could do it to his satisfaction. If anything went wrong with the engine anywhere, the owners soon learned that it was quickest put to rights if Murdock could be secured. He made a great many inventions and improvements to facilitate the manufacture of the engines, machines for casting, boring, turning and fitting.

He devised a machine for turning oval forms, and used the endless screw and gear for boring. He invented the well-known cement for iron made from cast-iron chips and sal ammoniac, and it became an extensive product at Soho.

Smiles credits Murdock with the invention of the famous "sun and planet" motion for avoiding Pickard's patent on the crank motion.

The patent was granted the firm for this in 1782, and Watt describes it as "his sixth arrangement revised and executed by William Murdock." In a letter dated the same year Boulton attributes it to Murdock, and Parks reports an interview with Watt, at which Murdock was

present, during which Murdock spoke of this device as his, and Watt did not contradict him.

In 1784 Murdock made a model locomotive of extreme simplicity that ran about the streets with no trouble whatever, but when Watt heard of it he wrote Boulton to "gently counsel" Murdock to give it up, lest it withdraw his interest from their work. That it was developed no farther goes to prove that this also was Murdock's invention rather than Watt's, as is sometimes asserted.

He invented in 1785 an oscillating engine. In 1799 there was a patent granted him for an improved method for the construction of steam engines. It included a dozen suggestions, but the most noteworthy was the proposal of a D-slide valve in the place of four poppets that Watt used in his double engines. Murdock was more than an excellent craftsman, however. He had something of Watt's habit of mind, and was constantly thinking and studying over mechanical and scientific questions.

As early as 1792 he began a study of different inflammable gases. His interest began from assisting Boulton in some of his chemical experiments, and his studies were carried on almost wholly in the night. He experimented with various substances—peat, wood, other substances, and coal of various kinds. He used an iron retort, and copper tubes of considerable length. He burned the gas at apertures of various shapes and sizes, and remarked the value of washing the gas in water. In 1794 he spoke about a patent on gas for illuminating purposes, but Boulton and Watt were too busy to attend to it, although later they expended large sums in the manufacture of gas producing machinery.

In 1802, to celebrate the peace of Amiens, Murdock

lighted by gas the whole front of the Soho works. This striking illustration of the usefulness of gas led Boulton and Watt to light their factory by this means. Other firms followed, and by 1805 gas came into general use.

In 1808 he read his famous paper on illuminating gas before the Royal Society of Edinburgh, and was awarded the Rumford gold medal.

In 1809 he discovered a method of refining porter by the use of fish skins in place of costly isinglass. That was very successful and profitable. In 1810 came his patent for boring stone.

It was a pet scheme of his also to use compressed air as a source of power. He used it to drive an engine, operate a hoist, and suggested the transmission of letters and parcels in tubes by exhausting the air, and experiments of his led his pupil, Samuel Clegg, to the project of the atmospheric railway.

Mr. Fairbairn tells of his pulverizing peat, compressing it into form and then polishing it into a beautiful jet black.

It was a whimsical suggestion of his, also, that the streets of London be made into a huge tread-mill, so that the energy of the walking multitude might be stored for useful purposes.

In 1824 Mr. Charles Dupin gives an account of the great meeting called to erect a monument to the memory of Watt, and records that reverence was made to the most interesting man present, a venerable man whose services should also be rewarded by some mark of public gratitude, and at the mention of the name, William Murdock, the great audience rose at once to honor him.

In 1830 he withdrew from active work and lived quietly near Soho until he died in 1839, aged eighty-five

years. He was buried in the same church near Boulton and Watt, and a fine bust by Chantry marks the spot. There is also an excellent oil portrait in the hall of the Royal Society of Edinburgh, of which he was a member.

William Murdock added to his mechanical sense a scientific mind, modest, unambitious ways, and a zealous friendship that made men love and respect him.

In nobility of character as in stature, he towered above his fellow men.

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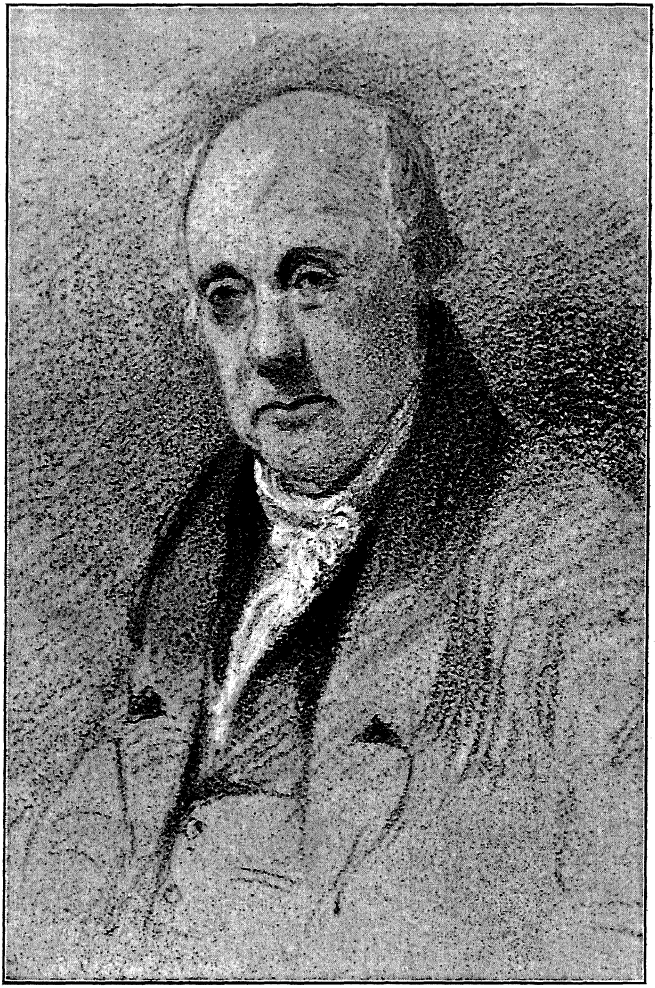

William Symington
1764-1831

William Symington.

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Another of the unfortunate engineers whose work was of real value in hastening the coming of practical steam engines was William Symington.

He was born at Leadhills, Lanarkshire, in 1764. His father was a miller by trade, who was in charge of the machinery at the mines of the Lead Mining Co., of Wanlockhead. This company had a Boulton & Watt pumping engine. William was carefully trained by his father in the company work shops and early gave evidence of mechanical ability.

He also had careful schooling which culminated in attendance at some of the lectures at Glasgow and Edinburgh Universities. Some writers say it was the intention that he should become a minister. Be that as it may, we know that at twenty-one he had constructed with his father's aid a model of a steam carriage that ran successfully about the streets of the village. It aroused great interest. Mr. Meason, the manager of the lead mines, exhibited it at his house, helped with the expenses, and finally sent William with it to Edinburgh with letters to some of the professors at the university.

James Watt heard about it and wrote to the young inventor as follows: "The sole privilege of making steam engines by elastic force of steam acting on a piston, with or without condensation, had been granted to Mr. Watt,

and also that, among other improvements, he had particularly specified the application of the steam engine for drawing a wheeled carriage, in a patent which was taken out in 1784." Evidently this threatening letter did not frighten Symington, for in 1787 he took out a patent for an improved steam engine in which he secured rotary motion by means of chain and ratchets.

Meason helped him build one of the same size as the Watt engine at the mines, and the two ran side by side under the same conditions, doing, it is said, one-fifth more work than Watt's engine.

At this time Symington came to the notice of Patrick Miller, a retired banker at Edinburgh.

Miller was a large owner of the Carron Iron Works, a man much interested in inventions and improvements of guns and warships. One of his schemes was to make a warship of two or three hulls covered by a single deck, with room between them for paddle-wheels, that were to be operated by sailors moving about a capstan. Such a ship was built, but the work was found to be too severe for continuous effort. James Taylor, a tutor in Miller's family, suggested a steam engine, and Miller finally gave him permission to find an engineer who could develop the plan.

Taylor introduced Symington and together they constructed a fine engine and boiler, and mounted them on a pleasure boat. The engine was constructed after the design of the 1787 patent, with brass cylinders four inches in diameter; the paddle-wheel was between the two hulls and was rotated by means of chains and ratchets. The boat was tried in 1788 on Dalswinton Loch in the park of Mr. Miller.

Aboard the boat were Mr. Miller, Symington, Rob-

ert Burns, the poet; Alexander Nasmyth, the artist father of James Nasmyth, the inventor who afterwards painted the picture of the boat that is given with this story. Also on the bank was Sir William Monteith, a future prime minister of England. Nasmyth describes the boat as being 25 feet long and 7 feet beam, made of tinned sheet iron. It was therefore, besides being the first steamboat, the first iron ship!

The boat ran four or five miles easily and was so much a success that Miller ordered the construction of a larger boat. Symington designed an engine with 18-inch cylinders, and the Carron Iron Works built it. It made seven miles an hour. Miller lost confidence in Symington's chain and ratchet gear and went to Watt for assistance, who took no interest in the proposal, and so the boat was dismantled and the matter was dropped.

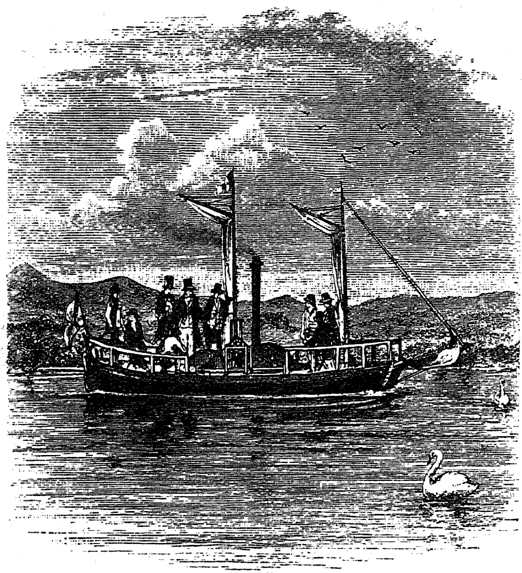
We hear no more of Symington for twelve years.

In 1801 Lord Dundas, the governor of the Forth & Clyde Canal Co., became interested in experiments for driving canal boats by power. He heard of Symington and employed him to design an engine.

Symington discarded his 1787 patent and took out a new one in 1801. This engine was a ten-horse power, lying horizontal on the deck. The piston rod was guided by rollers and was connected directly to the paddle-wheel shaft by a crank and connecting rod, exactly the way that has been universally followed since.

The engine was fitted to a tugboat called the Charlotte Dundas, 56 feet long, 18 feet beam, 8 feet deep. It had a hole 4 feet wide and 12 feet long in the stern in which the paddle was placed. The entire cost was £36 10s. 10d.

This boat was tried in 1802 on the Clyde Canal and



Designed and built by William Symington

The original of this was a painting by Alexander Nasmyth, who was one of the guests on its trial trip. He was the father of James Nasmyth, the inven or of the steam hammer.

ran from Lock 20 to Port Dundas, 19½ miles, in six hours. It was done in the face of head winds that drove all other boats to shelter, and, besides, towed two heavy barges.

It was guided by two rudders connected by an iron rod and placed on either side of the prow.

The experiment was counted a great success, and entitles Symington to great credit for designing and constructing the first practical steamboat on the lines that have since been followed. Fitch, the American, preceded him in the invention of the first steamboat, but that used oars and crude devices that were never reproduced.

Symington's fame seemed assured, but the governors of the canal company decided not to use steamboats on the canal from fear that the waves would wash the banks.

But the Duke of Bridgewater ordered him to construct eight for use on his canal. Just as he was ready to begin the Duke of Bridgewater died and Symington found himself friendless. His 1801 patent was found to be limited, and others by slight changes reaped the benefit that belonged to his genius.

Symington worked for a time for the Callinder Coal Co. and then drifted to London a disappointed and discouraged man. He did nothing more with the steamboat. It has been claimed and denied that Fulton was aboard the Charlotte Dundas, took up its design and with the aid of Fitch's drawings, Livingston's money and his own very great mechanical judgment, was able to construct the steamboat that survived.

Bell was another who observed Symington's work, and ten years later built the first commercially successful passenger steamer in England.

Symington lived a precarious existence until 1825, when he received a grant from the privy purse of £100 and later an additional grant of £50, but failed to receive an annuity. The London steamboat proprietors also gave him a small grant. He died in 1831 and was buried in St. Botolph, Aldgate, London. He was a good mechanic, but one who lacked force of character.

Many years after a granite column was erected at Leadhills, Lanarkshire, his birthplace, and a marble bust, made by D. W. Stevenson, was placed in the Edinburgh Museum of Science and Art, to his well-deserved honor.

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Richard Trevithick

1771-1833

Richard Trevithick.

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Richard Trevithick was the first to apply steam to the haulage of loads on railroads. He was born in 1771 at Illogan, a few miles west of Redruth, in Cornwall, in the midst of one of the richest mining fields of England. His father was a purser in some of the mines, a man of some property and standing. Evidently he permitted his son Richard to grow up without much oversight or restraint.

The boy thus grew up without the benefits of school discipline, spending his days among the mines and engine rooms, picking up information that afterwards was of service.

His father seeing his bent toward mechanics was wise enough to foster it, and placed him for a time with William Murdock, who was then at Redruth setting up pumping engines for Boulton and Watt.

He was naturally a skillful mechanic, enterprising, industrious and thoughtful. He doubtless learned much from his associations with Murdock, who was the ablest mechanic of his times. Among other things he must have known of the ingenious model of a steam carriage that Murdock built while there.

There was great demand about this time for engineers to set up and run the many steam engines that Boulton and Watt were building, and Trevithick very

soon found employment in this work. His father was astonished at his presumption, for he was still in his teens, but events proved him fully capable for the position. He was tempted, however, by the profits earned by Watt's engines to construct one that would evade the Watt patent and still be successful. With this in view he went into partnership with one Bull, who had designed a direct pumping engine.

This engine, under Trevithick's oversight, was a success mechanically, but in the ensuing law-suits with Watt they were defeated, and the partnership was dissolved.

A few years later we find him in partnership with a cousin, Andrew Vivian, engaged in the manufacture of engines, at Camborne, near his old home.

Trevithick was very ingenious, and contrived in many ways to improve the engine. The Watt patent expired in 1800, and thereafter others were free to use his designs, but Trevithick had already entertained the idea of using the expansive force of steam directly without the intervention of a condenser, and embodied his improvements in a patent that he received in 1802, for "the application thereof for driving carriages and for other purposes."

This was the first practical embodiment of the use of high-pressure steam without condensation. The engine was exceedingly simple, effective and economical.

Trevithick used a cylindrical wrought-iron boiler, similar to the one previously used by Evans in America.

Such boilers were long afterward known in Cornwall as Trevithick boilers. So economical were they that one company gave him a present of $1500 in acknowledgment of the benefit they had derived from their use.

The piston of the engine worked in guides and was fastened to a cross-head. This cross-head was connected by two side-rods to another cross-head on the other side of the shaft and the connecting rod was fastened to the second cross-head. The shaft was connected to the wheels by toothed gears. The carriage was the most compact and sensible of any to be invented for a long time after.

It consisted of a carriage capable of seating a half dozen, underneath which was the enclosed engine. It rested on four wheels, the two in front serving as guides, the two in the rear being driven. He used a fan for blast, but also exhausted his steam into the chimney. His patent speaks of making the periphery of the wheels rough or toothed, but adds that a smooth wheel "in general will be found to answer the intended purpose."

In 1803 the first steam carriage was built, and run about the town very successfully as long as steam could be kept up.

The success was so great that it was decided to take it to London. It went by road to Plymouth, about ninety miles, and thence by boat to London. It was so successful that it became the talk of the town. Such men as Sir Humphry Davy and Giles Gilbert rode upon it and great crowds came to see it.

Suddenly Trevithick withdrew the engine, sold the carriage to one man, and the engine to another, and returned to Cornwall. What his reasons were, no one knew, but it illustrated a trait of character that in the end ruined his life and deprived him of the honor and rewards that were his desert.

The same year, 1803, he went to Pen-y-darran, in South Wales, to erect a forge engine that he had built,

and when it was done began the construction of a railroad locomotive, the first ever constructed. Tramways were in use in many places at this time, and an excellent one near by probably suggested to him the thought of using his steam carriage upon it. It was finished and tried in 1804. It had a wrought-iron cylindrical boiler with internal fire-box and round flue that doubled on itself so that the chimney was at the same end as the fire box. The cylinder was 4¾ inches in diameter, placed horizontal in the end of the boiler. The piston worked in guides and was fastened to a cross-head, from which two long connecting rods went on each side of the boiler to cranks at the rear.

This shaft carried a big fly-wheel, and was geared through intermediates to the four wheels, which had smooth rims. It was used for bringing down iron from the old forge.

It worked well, and under forty pounds steam pressure made five and one-half miles an hour with heavy loads. But frequent accidents resulted from the weight breaking the flimsy iron rails, and she finally was ditched and then used as a stationary engine. This engine was an astonishing success. It was a compact, simple mechanism working on high-pressure principle, capable of carrying coal and water for a considerable journey, and at the same time drawing heavy loads at a speed of over five miles an hour.

It used both fan and exhaust steam for blast, and had smooth tread to the wheels. This was indeed the beginning of modern locomotives.

But instead of following up his success, Trevithick went back to a general engineering practice. In everything he undertook he was sure to introduce novel and

excellent features, still there was sure to crop out that lack of persistence to bring to naught his excellent beginnings.

In 1806 we find him entering into a contract to lift up from the bed of the Thames the ballast for all the shipping, a matter of 500,000 tons. This involved huge chain and bucket dredging machines. Two engines were already built, when he quarreled with the capitalists, and the contract was never sealed.

Nevertheless his engine business prospered, and he was on the high road to success. But his very success in the Cornwall district seems to have unsettled him. He kept suggesting new and radical changes, and finally left to go to London.

In 1808 he took out two patents for discharging ships of their cargo, and stowing cargoes by machinery, in 1809 another patent for constructing docks, ships and propelling vessels. This last patent covered the use of wrought-iron plates for naval construction that with cheap steel has come into general practice.

While Trevithick was in London he undertook the the most astonishing task of tunneling the Thames. It had been suggested some years before, but in 1807, when Trevithick became the engineer, the task was pushed. In five months over 900 feet were dug, when a series of mishaps interfered. Still he persisted until, after 1,100 feet had been completed, he was forced by frequent and serious breaks to give up the undertaking. In the years that followed he took out two or three patents for novel engines and boilers. In one he specified and described our modern screw propeller. His success in the construction of pumping engines brought him to the attention in 1814 of a company engaged in pumping out abandoned

silver mines in Peru. A number of his engines were purchased, and he with others went with them to erect and to participate in the enormous profits expected. At first great success was theirs, and Trevithick computed his share as certainly $500,000 a year, when suddenly, in 1818, a revolution ruined the company, and Trevithick with one or two others escaped with their lives northwest to Panama. Here, ragged and penniless, he met Robert Stephenson, who assisted him home to England, which he reached after a serious shipwreck in 1827. He took out two more patents, one in 1831, a method of heating apartments, and the other in 1832, for improvements in the steam engine; but neither was of moment, except that the latter included the use of superheated steam, and the use of the impact of high-pressure steam directly against water as a means of propelling a boat.

Strange to say that in spite of all that he had done in inventing the locomotive, he should have taken no part in the interesting developments of 1829-1832, with which the name of George Stephenson is associated, and the ultimate triumph of the locomotive.

Instead, during those years he gave all his thought to inventing a steam wagon to run over the highways, and to the perfecting of his steam jet propulsion of steamboats. While thus busied he died in 1833, when sixty-two years of age.

As he died with no means and deeply in debt, the workmen at the shop where his inventions were being developed contributed enough to bury him, but no stone marks the resting-place of this great but vacillating mechanic.

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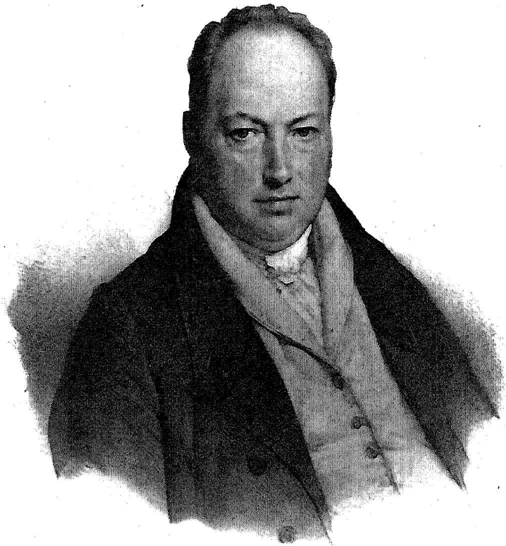

Henry Maudsley

Henry Maudsley.

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Henry Maudsley was the originator of modern machine tools. He came of an old English family who had their seat near Ormskirk, but who became scattered during the eighteenth century. William Maudsley, father of Henry, was a joiner working in the neighborhood of Bolton. He got into some trouble and joined the Royal Artillery, to be sent, soon afterward, to the West Indies, where he was badly wounded. He was sent home, and afterwards discharged, but being a handy workman was soon employed in the arsenal. Here he was married and Henry was born in August, 1770. When twelve years of age he was sent to work filling cartridges, and two years later he was set at work in the carpenters' shop. His heart, however, was in the nearby blacksmith shop, and after several reprimands for neglecting his work he was transferred to the smithy when fifteen years of age.

His heart was in this work and he rapidly became an expert craftsman, especially in forging light iron work, and, in the use of the file, he soon surpassed all others.

At this time Joseph Bramah had taken out patents for improved locks of the now well-known tumbler type. These were a great improvement over previous locks. Bramah challenged any one to pick a lock of his manufacture, and the challenge was unaccepted until fifty years

later, when Hobbs, an American expert, after sixteen days of effort, finally succeeded.

This lock was so delicate a mechanism that he found difficulty in securing workmen skillful enough to make them. Maudsley was recommended to him, but when Bramah saw how young he was, at that time only eighteen, he hesitated to employ him. His need was so great, however, that he finally hired him. When Maudsley presented himself for service a new difficulty arose. He had not served the requisite seven years of apprenticeship and the other workmen refused to receive him.

Maudsley himself solved the difficulty by proposing the repair of a worn-out and broken bench vice before six o'clock, and if his workmanship did not commend him he would withdraw. His success was complete. The most exacting of the workmen acknowledged his skill. The tact and good sense thus early shown were characteristic of him in all his relations with his workmen.

Maudsley soon proved himself to be the most skillful of them all. It is interesting to note that the very padlock that fifty years later withstood the American expert for sixteen days, was one made by Maudsley's own hands when in the employ of Bramah.

He had the surest eye and the best judgment in undertaking any new work, and it was more and more referred to him.

Notwithstanding his youth, he was advanced from place to place until, by unanimous consent, he was made the head foreman.

Maudsley saw at once that it was essential, if the locks were to be manufactured in any quantity, that the parts must be made by machines that would be independent of men's carelessness. Skilled hand work could

make a few, but the number were limited, the expense great and the merit very unequal. He became especially useful in designing special tools for making the patent locks. Smiles says: "In this department Maudsley was eminently successful, and to his laborious ingenuity, as first displayed in Bramah's workshops, and afterwards in his own establishment, we unquestionably owe much of the power and acccuracy of our present self-acting machinery."

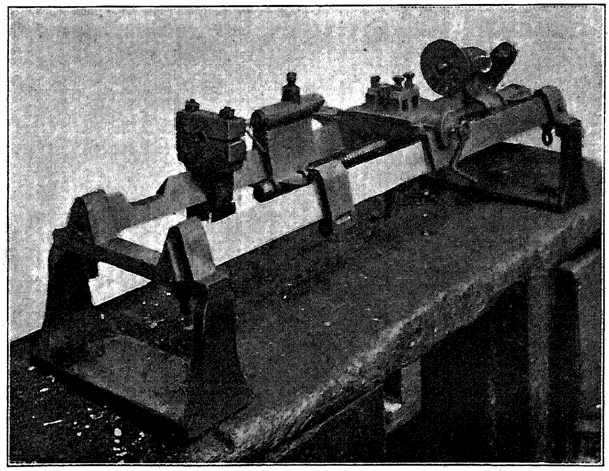
Another of his inventions, that alone should bring him fame, was the leather self-tightening collar for packing hydraulic presses. It was Bramah again who patented the press, but its usefulness was nullified by the packing necessary to withstand the enormous pressure. It was Maudsley who designed the leather cup that clings the closer with added pressure but without noticeably increasing friction.

Maudsley stayed with Bramah eight years with but slight increase of wages, and when he, at last, asked for an increase was refused so brusquely that he resigned, and in 1797 opened a small shop of his own near Oxford Street. Little by little work came to him, and every task was so nicely done that it invariably brought him new work. Maudsley continued to apply himself to the invention and improvement of tools that would insure precision of work and make him, in a measure, independent of the carelessness of workmen. It was in this endeavor that he brought to perfection that great improvement with which his name is usually connected, the invention of the slide rest. The first he ever made was while he was still at Bramah's shop, but with his additional improvements he brought the lathe, for the first time, to be a machine of precision, and laid the foundation for the success of all

our modern machine tools. Before this, nicety of construction depended altogether on correctness of eye and manual dexterity, with consequent high cost and unequal merit. Thereafter followed that correctness, uniformity and economy that increasingly marked the machine construction of the nineteenth century.

One of the early tasks that came to Maudsley was brought by Brunel. He had been granted a patent for tackle blocks which had been adopted by the admiralty. Maudsley's high reputation came to Brunel's attention, and he was engaged to perfect the machinery for their manufacture.

Maudsley, who was a fine draftsman, made the drawings and the working models in 1801. Before beginning



Maudsley's Lathe

construction he removed his shop to Margaret Street. The whole of the machinery was there constructed by

Maudsley. It took six long years, and was not ready for operation until 1808. It required no less than forty-four different machines to do the work, every one of which embodied some more or less radical invention and improvement by Maudsley. These machines were in regular employment at the Portsmouth dockyard for upwards of fifty years.

The success of this block-making machinery brought Maudsley added fame and prosperity.

He moved again, this time to Lambeth, and took in a partner in 1810, the company thereafter being known as Maudsley & Field. They made many and various kinds of machinery, flour mills, saw mills, mint machinery, machine tools and engines of all kinds, especially marine engines. A patent granted in 1807 for improvement in steam engines, specified, among other things, the now common pyramidal type of marine engine, with direct connections from piston to crank. He invented a machine for punching boiler plates, and continued to improve the lathe as long as he lived. He made some large machines, but he took the greatest interest in machines of delicacy and precision.

His love for accuracy early led him to give thought to improvement in screw cutting. He made a machine for cutting original screws and from that made the first screw-cutting lathe. He also took the first steps for securing uniformity and standard pitch.

Like all good workmen he took great pride in keeping his tools in good order and condition. Every machine to which he gave thought came from his hand simplified, improved, and wih the impress of his personality upon it.

But that for which Maudsley is most worthy of remembrance is not the machinery he built, but the men he trained. His exceedingly attractive nature, his tall, fine presence, his genial ways, bound men to him; not

only his friends, but his workmen loved him as a man, while honoring him as a master workman. It was quite natural that there should gather around him a group of assistants who were young men of ability and worth. In fact his shop came to have a reputation all over England as the place for securing the best mechanical training. It was with him that such men as James Nasmyth, Sir Joseph Whitworth, Joseph Clement, and a host of others received their training. This training was not in mechanics alone, but in the wise comments and advice that fell from his lips and, like seed falling in good ground, sprang up, in the years that followed, in the able life of his "boys."

He had his friends also among the foremost scholars and scientists of the day, who made his private workshop a favorite rendezvous. From his shop radiated an influence that is plainly seen in the wonderful development of mechanical engineering in England from his time on. Under his training such men as Nasmyth, Clement and Whitworth, and others received their training, and from them his influence passed on to Sellers and Colt, to E. K. Root, and Francis A. Pratt, to shape also our American practice.

In personal appearance his was of commanding stature, six feet two inches tall, and massively built. He had a high forehead, eyes bright and keen, lips expressive of good humor, but strong and alert. He was cheerful, honest, intellectual and energetic.

He went to France to see a friend who was very sick and, on returning, caught a severe cold, from which he died in 1831.

▼ ▼ ▼

George Stephenson

1781-1847

George Stephenson.

▼ ▼ ▼

The success of George Stephenson was the natural result of steady, patient, hard work. He had very much to contend with in the beginning and won out by well directed energy. Stephenson's life was ideal, in a way. It passed through want, desire, struggle; to achievement, honors, leisure and comfort.

His parents were very poor colliers of the north of England, of Scotch and English blood. He was born in 1781 in the midst of the harshest social conditions. Poor as he was, however, it is remembered that Stephenson's father was a great favorite with the villagers and the children, and had a very strong love for birds and all nature. George thus came naturally by his characteristic good cheer, affection and love of nature. As a mere child he began to work, being taken on at the mines at a pitifully young age to pick out stone from the coal. Then he was advanced to driving the gin horses.

Long as were his hours and hard as was the labor, he found time to play, to build clay engines, and make pets of all sorts of birds and animals. He was so young when he was taken on as an assistant fireman with his father that he used to hide when the owner came around, lest he be discharged as too small for the responsibility. At fourteen he was made first assistant at a shilling a day. At this time the family of eight were living in a one-room

cottage. At fifteen he was made a fireman. Then he became ambitious to be an engineman—and to this end he made every effort to prepare himself—still he had time for play, and at this age he took the most interest in feats of strength, in which he was very successful, lifting weights and wrestling.

At seventeen he was made "plugman," one step higher than his father. This was in the days when "automatic" machinery was unknown, and George's place required much skill and judgment to regulate the pump to suit the varying conditions of water and steam. In his study he found excuses for taking his pump and engine apart for cleaning or repairs—until he became expert as an engineman.

He began to appreciate his loss in not being able to read—and big as he was he began to go to school evenings, and saved every penny he could for the expense. He kept on making clay engines and experimenting with everything in his way. At nineteen he could read, and write his own name, and began to study arithmetic. At twenty he was made brakesman, and secured a night appointment so that he could have more time to study arithmetic and mend shoes for his fellow workmen.

At twenty-two he was made a full engineman, and married, but continued just the same his evening study and experiments. It cost him more to live, so he took on more outside work, mending clocks, shoes, and, hardest of all, shovelling ballast from the ships that came for coal. In 1803 was born his only son, Robert, who became his great comfort, pride and assistant, an engineer second only to his father in ability. In 1805 Stephenson's name for a sober, skillful "engine doctor" was becoming known, and he went from one position to another, being sent for to

remedy troubles with engines, pumps and winding machines. This brought him his first salaried position, enginewright for all the pits of the Grand Allies.

His only child, Robert, was becoming old enough to be sent to school, and he redoubled his efforts to earn money. As years went by they worked and studied together, a mutual comfort and inspiration. Robert studied or read aloud while the father continued his experiments and inventions until their cottage became a museum of mechanics. As engineer, Stephenson now began to make improvements in the colliery outfits, and the improvements that first interested him were the tramways from the pit to the dock. He improved the rails, and made the first incline in his district on which the loaded wagons descending hauled up the empties. He had already begun to give intense thought to the substitution of engines for horses where the inclines were not possible This was in 1813. Many other men had been at work on the same problem with more or less success. There were Cugnot, the French engineer, Moore and Murdock, the Englishmen, and Evans, the American.

There were others of his own day who were still working at it. Trevithick, the pupil of Murdock, was as much the inventor of the locomotive as anyone and was on the verge of a great success, but missed it by cumbering his experiments with toothed wheels, intermediate gears, and mechanical draughts. His impatience lost him success and credit. Blenkinsop's engine ran for many years, even after better ones were invented.

Mr. Blackett, the owner of a neighboring colliery, persisted in his efforts to get an engine to haul coal on his tramway and finally discovered that the traction of a smooth wheel on a smooth rail was sufficient, and that

all the cogs, racks, spurs, and endless chain were useless, but he could only draw about three miles an hour. After all these came Stephenson, and by his better mechanical judgment and patient energy brought the problem to a successful conclusion.

He first visited and inspected a Blenkinsop engine and the engine at Mr. Blackett's, and then constructed his first "traveling engine," the Blucher.

Space will not allow details; sufficient it must be to say that it drew thirty tons at four miles an hour on an up grade of 1 in 450, and continued to do so for four years. This engine, no more economical than horses, was the best up to that time, but when Stephenson turned his exhaust steam into the chimney for forced draught, he doubled its effectiveness at once. In 1815 he built a new engine that was a decided improvement. It had simple direct connection to drive-wheels, on smooth rails, parallel connection with the other wheels, exhaust steam draught, and a substitute for springs to alleviate the evils of rigidity, the germ of the modern locomotive.

We ought to stop here long enough to tell of his invention, quite independently, but at the same time with Sir Humphry Davy, of the first practical safety lamp for use in coal mines—something that has done more than any one thing else to make the life of coal miners bearable. To bring the safety lamp to perfection he risked his life again and again. It was only a small part of his time that he could give to it, but he gave it gladly from personal knowledge of the terrible dangers to which the miner was continually exposed.

Stephenson's main attention was more and more given to the improvement of the machinery under his charge, of which the tramways and engines were no small

part. He invented a lap-jointed cast-iron rail that rested on an improved chair that was a great improvement on the old-style plates that butted together on a flat chair. With this patent were coupled some improvements in the locomotive also, the most notable of which was the introduction of steam cushions to overcome the evils of irregular road-bed and rigidity. Stephenson's good judgment was shown at this time in refusing to try to adapt the locomotive to common road traveling, a conclusion to which he came after careful experiments on the resistance to traction. Although his locomotives at Killingworth were in operation for some years, they excited little outside interest.

In 1819 another mine determined to build a tramway, and employed Stephenson to engineer it. This was successfully accomplished in 1822, when five locomotives were each hauling 64 tons at four miles an hour. At this time his son, Robert, was of great assistance to him, but he resisted the temptation to take him from school, and at great expense sent him to Edinburgh University. The son repaid this by taking down the lectures in full, and reading them afterward to his father. In 1821 the Stockton and Darlington road was proposed, and Stephenson was again secured as engineer. He had already become a partner in an iron foundry, and now he became partner in the first locomotive factory.

This road was open for traffic in 1825, using Stephenson's locomotives. The first train consisted of six wagons of coal and flour, a passenger car for the directors, twenty-one temporary wagons for spectators, and then six wagons of coal. The speed reached six miles an hour. The road was a success from the beginning, but much to the surprise of all, the income came, not

from local sale of land and coal as expected, but from passengers and through coal. The latter shipments increased in a few years from almost nothing to 500,000 tons a year.

The success of this road was the turning point of railway construction. Before it was ready the plan for a railroad from Manchester to Liverpool was under consideration to relieve the canal congestion.

Mr. Stephenson's energy and good judgment commended themselves to the directors, and he was made engineer of this line also. But so strange and flighty did his plans of running twelve miles an hour seem to Parliament, when a charter was sought, that the charter was at first defeated; after discharging him the charter was secured a year later, but when the actual building was to be undertaken he was again secured; there was no one else who was fitted to overcome the tremendous difficulties of bog and mountain and personal hostilities.

On this road of twenty-nine miles, there were miles of bog, miles of tunnel; there was a two-mile cut of eighty feet deep in places out of solid rock; there were sixty-three bridges including a great viaduct seventy feet high. All of this was accomplished in some seven years, with unskilled engineer assistants, and the bitterest hostility of land owners and canal rivals. Not until 1828 was it even decided not to use horse power, and then came the battle between stationary engines and locomotives, Stephenson sturdily advocating the latter.

At last he secured the adoption of the locomotive, and then the vote to offer a prize for the best one to be ready for duty on the completion of the road-bed. There were four competitors, of which Stephenson's "Rocket" was the winner. All others failed on some of the re-

quirements. Stephenson's alone met them all, and surpassed some. The first charter was defeated because Stephenson mentioned twelve miles an hour as a possible speed. At the test the Rocket actually went at the rate of thirty-five. The improvements that Stephenson had introduced in this engine were vital; the boiler was multitubular, cylinders outside, and a reduced orifice to the exhaust steam blast in the smoke-stack.

The boiler was six feet long, three feet four inches in diameter. The lower half was filled with three-inch copper tubes. The two cylinders were inclined and coupled directly to the single pair of drive wheels. The whole including its load of water weighed four and one-quarter tons and rested on four wheels.

Of the other engines that competed, Ericsson's Novelty was the only one that needs notice. At first it was the favorite. Its speed was even greater than that of the Rocket, but its extreme lightness resulted in frequent breakage and its mechanical draught was not a success. At last it withdrew, leaving the field entirely to Stephenson.

From this time on Stephenson's reputation was safe. By 1835 he was acting as engineer or consulting engineer for a score of railways. He worked day and night; a week in Scotland, the next in England, and the next in Ireland; then back to London for committee meetings; then to his locomotive works, and then back again surveying. In 1837 he traveled 20,000 miles in post-chaise. He employed a secretary, who followed him about, and often wrote thirty to forty letters a day—letters of technical detail, argument for committees, reports for directors, and plans for improvements. On one occasion he dictated continuously for twelve hours.

Stephenson.

Fortunately, Stephenson had perfect health, and could command sleep at a moment's desire. He had been trained in a hard school, and could bear with ease conditions that prostrated his assistants. He was sent for by European governments for advice, and became a great social favorite, as his vivacity and cheerfulness, strong good sense and affection won his way with all. He chatted with the Queen, and the King of Belgium, and Sir Robert Peel as simply and interestingly as he did with his old colliery mates.

As he passed beyond sixty years of age, he gradually withdrew from affairs, passing over as much as he could to his already famous son. Then he threw his energy into his private business, and more and more of it into the life of a country gentleman; raising fruits and prize animals, taking as much interest in making a cucumber grow straight as formerly in making locomotives. No man enjoyed his latter days more highly than did George Stephenson, and no one better deserved the affection of all than did he. From the first he had been honest, cheerful, and generous. Ever ready to give credit and praise to his assistants and associates, none ever repaid their chief with warmer loyalty than they.

George Stephenson was a great engineer. First of all he was practical. He was not a dreamer. He was inventive, but coupled with it great sagacity. He asked, first of all, can it be done? and then, will it pay? He was thoroughly honest, a safe man to follow. But he was more than a great engineer, he was one of Nature's noblemen—healthy, energetic, thoughtful, cheerful, generous, and affectionate.

Emerson said of him, "It was worth crossing the Atlantic to have seen Stephenson alone; he had such na-

tive force of character and vigor of intellect." His native modesty, quite naturally refused knighthood when it was offered.

He died quietly in 1847 at sixty-eight years of age. His body was followed to the grave by a great concourse of working people, and his memory was honored by high and low everywhere.

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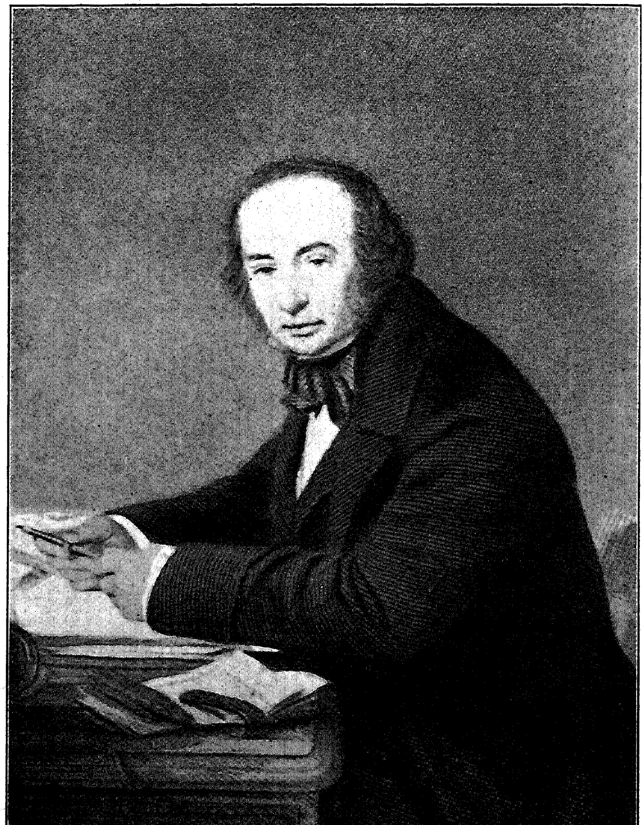

Isambard Kingdom Brunel

1806-1859

Isambard Kingdom Brunel.

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Although Mr. Brunel could hardly be called an inventor, yet he played such an important part in solving the engineering problems incident to the introduction of railroads and steam navigation, that we can not justly omit him from the list.

He was born in the midst of engineering problems, for his father was Sir Marc Isambard Brunel, the famous designer of the plans for making tackle blocks by machinery, which we read about in the early life of Maudsley. His father was an officer of the French Navy at the time of the French Revolution. Because of his strong Royalist sympathies, it was dangerous to remain and he escaped to America. He landed at New York in 1793 and obtained employment as a civil engineer. In a few years he became engineer for the State of New York and while in that office designed a cannon foundry and other public works. In 1799 he went over to England and engaged in general engineering work, was married and Isambard was born in 1806. He was educated in private schools until 1820, when he attended college at Paris. From the time he was four years old he showed a talent for drawing which his father cultivated and trained until he became an excellent draftsman while still in his teens, his drawings being exceptionally precise and neat.

From 1823 he was regularly employed in his father's office in London. His father was engaged at this time on the plans for several suspension bridges and, of most importance, a tunnel under the Thames.

This was a new venture and full of engineering difficulties. It had been tried by Mr. Trevithick in 1807, but only the beginnings were made when it was abandoned, leaving no fund of experience to guide latter attempts Sir Isambard was obliged, therefore, to originate his own method.

His method was to sink a shaft about 50 feet deep and at the bottom to tunnel straight ahead, lining the tunnel with brick as he proceeded. The soil was clay, with frequent seams of mud from the river above. His shield was composed of a row of twelve cells that, together, made the face of the bore. Each cell was pressed against the face to be excavated by jacks placed against the edge of the brick work already constructed. A workman would enter a cell, dig out the mud in front of him, force the cell forward to fill up the hole and then brick up the tunnel back of him. Then do the same at the next cell, and so on. There were, of course, other devices for protecting the face of the cells and the space between the brick and cells.

Borings were made, but not as carefully as would be done now, and their troubles increased with repeated breaks and floodings. Work was abandoned January, 1828, after completing only 600 feet.

During these five years Mr. Brunel took an increasingly responsible part. He was only twenty-two when the work was abandoned, but, as resident engineer, was watching the shields night and day and, after the final break he was the one who descended in a diving bell to

the bottom of the Thames to see what manner of a hole it was and what damage had been done to the brick work.

With this five years' experience Mr. Brunel set out to establish himself in an independent engineering business. Years later, when work was resumed on the tunnel by the father and it was brought to completion, the son was too busily engaged in his own enterprises to have part in it.

For two years Mr. Brunel devoted his time to study and observation with Mr. Babbage, Prof. Faraday and other scientific friends.

In 1829 he submitted three designs for a suspension bridge at Clifton, that revealed those traits that characterized his work to the end, namely, boldness and architectural beauty. A second competition was held a year later and again Mr. Brunel's design was approved and this time accepted and he was made engineer. The construction was not begun until 1836. The bridge was 700 feet span and the roadway 248 feet above high water. During his life Mr. Brunel built many other bridges of timber, wrought iron, and suspension, all of which were marked by the same bold originality.

The largest of his bridges was the Royal Albert, which carries the Cornwall Railway across the River Tamar at Saltash. The river is 1,100 feet wide and 70 feet deep. This bridge had two spans of 455 feet each and the approaches made up a length of 2,200 feet. The center pier was a 35-foot circular cylinder, resting on rock 87 feet below high water, and filled with concrete. This was carried up 12 feet above high water and on it rested four cast iron columns to the level of the railroad, 100 feet above high water. Each truss was a combination of two huge suspending chains and a wrought iron oval tube

16 feet 9 inches in its largest dimension. The rise of the arch was equal to the fall of the chain and, being connected at the abutments, the outward thrust of the arch was counterbalanced by the inward pull of the chains. The bridge was completed in 1859, the same year in which he died.

But the bridge building of Mr. Brunel was only incidental to his railroad work. As early as 1833, when railroad building was in its infancy, he was made engineer for the construction of the Great Western Railway. His preliminary surveys were soon made, but it was 1835 before the charter was granted.

Brunel was at this time only 29 years old, but was already counted one of the best engineers of his day. With characteristic boldness he attacked the problems and, as usual, settled them radically different from the customary way. He decided, first of all, to adopt the pneumatic system of propulsion. He was not its inventor, but after considering the nature of the country and the expense of operating steam locomotives, he decided that the pneumatic system was most promising.

This system called for a long tube placed in the ground midway between the rails. This tube had a slit its entire length, which was ordinarily closed by a flap-valve. At regular distances, air pumps were located which exhausted the air from the tube in front of a train. The motor on the train consisted of a piston fitting in the tube and connected to the car by a narrow bar arranged to automatically open the valve just behind the piston as the partial vacuum drew the piston and cars forward. It was easy to figure the economy of this system in advance, but in practice unforseen mechanical difficulties continually troubled them until the system was abandoned in 1848.

In the matter of gauge, also, Mr. Brunel stood alone. He foresaw that, for economy, railroads must be designed to operate heavier equipment than in use at that time. The 4 foot, 8½ inch gauge, already standard in the North and East, seemed to him to limit any increase of weight or speed. He, therefore, built the Great Western with gauge of 7 feet and constructed his engines and cars of unprecedented size. Later on, as this system came into contact with the other systems, the inconveniences were so great that they had to give way and equip the line with a third rail so that narrow gauge standard cars could also move without unloading, and still later the broad gauge was discontinued altogether.

In choosing the broad gauge, Mr. Brunel showed the better foresight and judgment, for unquestionably it would be an advantage if a broader gauge than 4 foot, 8½ inch had been made the standard.

A unique plan of his was the erection of a great terminal hotel at the London station.

Still another plan was to prolong their railroad line by a line of steam boats to run regularly in connection with the railroad from Bristol to New York. At first his recommendation was treated as a joke, but after he had proved to his directors the possibility of a steamship carrying coal enough to reach New York, they adopted his plan and authorized him to proceed with the construction of the first steamboat designed to make regular trips across the Atlantic.

His main point was, that the work of propulsion increased about as the square of the dimensions of the boat, but that the capacity for carrying increased by the cube. This was vehemently denied by experts of his day, but has since been universally accepted. His directors

showed their faith in him by enabling him to construct the Great Western steamship It was completed in 1838. The papers of the day spoke of "her magnificent proportions and stupendous machinery." She was 212 feet long and 35 feet 4 inches broad. Her engines were made by Maudsley & Field, cylinders 73½ inches, stroke 7 feet. She made her first voyage in 15 days and had 200 tons of coal left over when she steamed into New York harbor. This one trip settled once for all the desirability of large steamers for ocean travel and the credit belongs to I. K. Brunel.

The Great Western Co., encouraged by the success of their first vessel, determined on the construction of one still larger, and, true to his nature, Mr. Brunel advocated still more novel features. This time he recommended that the new vessel, to be called the Great Britain, be made of iron and with a capacity of 3,443 tons burden.

They also decided, this time against the advice of Mr. Brunel, to build their own engines. For this they erected and equipped very large shops, and thereafter Mr. Brunel had the engineering oversight of them, also. Before the vessel was completed, in 1840, the use of the screw propeller in ocean navigation was suggested. Mr. Brunel made a careful study of the subject and in his report urged the company to adopt the screw propeller in the place of side wheels. His recommendation was accepted and the Great Britain became the first ocean going steamer to use the screw propeller. Mr. Brunel took great pains in designing the structure of this vessel, with such success that she withstood being wrecked in 1846. She had been practically abandoned when Mr. Brunel went to examine her. He reported in great heat that she was practically unhurt and protested against abandon-

ing her. He protected her from the winter storms and later floated her, and on examination was found to have suffered no general damage. She afterward did good service for 40 years on an Australian line. She had five water-tight bulkheads and, among other interesting features, may be mentioned a balanced rudder, two bilge keels, but no central keel, and a hollow crank-shaft. The boilers were a group of six, back to back, and were found later to be insufficient. They were run at only eight pounds pressure. The power was transmitted to the propeller shaft by chain and sprockets speeding the latter, three to one. She was 322 feet long, 51 foot beam with displacement of 3,000 tons. Her engine had four cylinders, 88 inches diameter and 6 foot stroke.

Soon after Mr. Brunel had recommended the adoption of the screw propeller he was called upon by the British Admirality to make experiments and investigations as to the advisability of adopting the propeller in the British Navy. So satisfactory was his report that by 1845 twenty vessels had been made over to use the screw propeller.

In 1851 Mr. Brunel became engineer of the Australian Mail Co. and built for them two successful ships, the Victoria and Adelaid. In 1852 the Eastern Steam Navigation Co. was organized to carry out a proposal of Mr. Brunel to construct a vessel of still larger dimensions. This was to be called the Great Eastern, and so bold was the design that it is only within a few years that her dimensions have been exceeded. She was built 680 feet long by 83 feet broad and 53 feet deep, with a gross tonnage of 18,915. She was divided into 11 water-tight compartments. The upper deck was made cellular and her skin was double, 6 feet above her water line, with

longitudinal webs. There were two longitudinal bulkheads 36 feet apart and 350 feet long extending to the upper deck, which added great strength to the ship when considered as a girder, and made her exceptionally staunch. Her power equipment consisted of side wheels, intended to do one-third of the propulsion, and a screw propeller for two-thirds. Her paddles were 56 feet in diameter, 30 floats, 13 feet by 3 feet, and her screw 24 feet in diameter with 4 blades, set at 24 feet pitch. The paddle engines could develop 1,000 nominal horsepower and consisted of 4 oscillating cylinders 16 feet 2 inches in diameter and 14 foot stroke, working in pairs on a single crank. The screw engine could develop 1,600 horsepower, consisted of 4 cylinders, 7 feet in diameter, 4 foot stroke, working in opposite pairs on a single crank. Besides these there were a number of auxiliary engines for hoisting the anchors, pumping, and operating the screw when in harbor. Her main boilers were ten in number, four for the paddle engines and six for the screw.

In addition she had six masts fully equipped with rigging and sails. With his usual boldness, Mr. Brunel built her level, with broadside to the river, and although she was successfully launched in 1860, yet there was considerable trouble which caused much anxiety to her engineer.

Meanwhile, the P. & O. Steamship Co. having received the monopoly of carrying the mails to the far East, the use of the great steamship was transferred to the Atlantic service, making a number of trips to New York at about 14 knots per hour.

Commercially she was never a very great success from her lack of adequate business, Mr. Brunel, in his characteristic boldness, having gotten ahead of the times.

She found her best use as a cable ship in laying the great ocean cables. At one time she carried a cargo of cable for Bombay by way of the Cape of Good Hope. With the cable and coal she drew 34 feet 6 inches with the enormous displacement of 32,724 tons.

At one time she was used as a transport, carrying comfortably over 3,000 persons, besides 200 horses, coal and freight. In service she proved very seaworthy and comfortable, rolling very slightly in the heaviest storms and carrying with ease enormous loads when laying ocean cables. She was notably easy to handle in narrow channels and ports because of her two sets of engines, it being possible to turn her easily in a very small area. Many minor features introduced by Mr. Brunel, such as jacketing all steam surfaces and superheating steam before entering the cylinders, have since been generally adopted.

Sufficient has been given to show the phenomenal capacity for hard work that lay in Mr. Brunel. We have, for convenience of narration, divided his labors in sections, but it is to be remembered that he was engaged in all at the same time. His greatest bridge, his greatest steamship, dock work, and railroad construction in England, Italy and India, were all going forward at the same time. In addition, he was interested in the construction of rifles and cannon and urged strongly on the Admiralty, a floating battery, that would have developed, if it had been built, into an armored gunboat.

Still another thing was his design, for the war office, of standard, expansible, iron buildings for hospital service in the Crimean war.

In private life Mr. Brunel was exceedingly cheerful and fond of recreation and pleasure. He slept very little, but worked early and late, taking his rest in laughter and

good cheer between times. His friends all spoke of his uniform kindness and unselfish friendship. Even some of his keenest professional rivals were his warmest friends, and in spite of the intensest differences of opinion on scientific questions he could hold their sincere friendship. It is said that no one ever saw him ill-tempered or biased in judgment of others. As an engineer, in spite of his boldness, he was singularly cautious, prudent and far-sighted. He died in 1859 of paralysis, aged only fifty-three.

James Nasmyth

1808-1890

By G. Reid, R. S. A.   Etched by Paul Rajon

James Nasmyth.

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We remember the name of James Nasmyth with the invention of the steam hammer, but he did many things, and did them well. He came of an old titled Scotch family whose records go back nearly a thousand years. They were staunch loyalists in the border troubles, at least until James II. tried to make Catholic their Scotch Presbyterianism. Once when sorely beset by the Scots, so runs the story, their ancestor took refuge in a smithy, and set to work as a striker. He wasn't very skillful, missed the iron and broke his hammer on the anvil. One of the Scots exclaimed "You're nae smith." Being discovered he seized a sword and, fighting fiercely, vanquished his enemies. They took the new name "Nasmyth," and the family arms became a sword between two broken hammers.

When their ancestors broke with their king rather than change their religion, they lost their property and from that time on were obliged to work hard and spend sparingly. Something of the refinement of the old life remained and showed itself in their skill in art and love for learning.

James Nasmyth's immediate ancestors were artists, and architects of note.

His father was the founder of the landscape school, a man of ardent temperament, and intense love of nature.

James inherited his father's artistic temperament, love of all things beautiful and delight in nature. He himself was an artist with pencil, and a finished draftsman.

There developed in him also a mechanical bent that came to dominate the artistic. As a mere lad he began to make things, and by the time he was sixteen he was skillful with tools and turned his bedroom fireplace into a foundry, making finished working models of engines, metallic mirrors and scientific apparatus.

Even as a lad he was very industrious. After fifteen he turned everything into the direction of the profession that he had decided upon for himself; that of engineering. He made journeys to see noted engines or processes; made drawings of unusual designs; sought acquaintance with successful engineers; saved all his spare earnings to attend technical lectures at the university. By nineteen his little models of engines had become real working engines used in neighboring mills. He even constructed a steam road wagon that carried six persons successfully—for the Scottish Society of Arts.

Before he was twenty he had determined to be a mechanical engineer, and having heard of Henry Maudsley, the greatest of the early machine builders, was taken to London by his father.

At first Maudsley refused to receive him, but later when he saw the beautifully finished drawings and models he had made, admitted him not as an apprentice, but as a personal assistant in his private experiments.

He stayed there two years, until after the death of Maudsley, then deliberately decided to go into business for himself.

He had but little money, perhaps $300. He set about

influence over men. There was no place in his great heart for professional jealousy.

He was an acknowledged authority by mechanical, civil and mining engineers alike, and capitalists entrusted their millions to him in perfect confidence.

He began life in perfect physical health, but his habit of intense and prolonged application told on him at last. As early as 1875, when only forty-three years of age, he began to feel the effects of the enormous strain. He was seriously ill in 1881, but recovered only to collapse again in 1882, from which he never rallied.

Unconsciously he pictured his own end one night at Pittsburgh, when he had been called from a sick bed to respond to a gift of plate from his associates. What could be more beautiful and pathetic than his closing words on that occasion:

"Among us all who are working hard in our noble profession and are keeping the fires of metallurgy aglow, such occasions as this should also kindle a flame of good-fellowship and affection which will burn to the end. Burn to the *end!*—perhaps some of us should think of that. who are 'burning the candle at both ends.' Ah! well, may it so happen to us that when at last this vital spark is oxydized, when this combustible has put on incombustion, when this living fire flutters thin and pale at the lips, some kindly hand may 'turn us down,' not 'under-blown,' —by all means not 'over-blown'—some loving hand may turn us down, that we may, perhaps, be cast in a better mold."

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enough to forge the 30-inch paddle shaft, to refer the difficulty to him. The result of his thinking was a sketch in 1839 of the steam hammer, but the change from paddles to screw propulsion for the Great Britain did away with the necessity of the shaft so that the hammer was not constructed until a year or two later.

This was first built without permission in France by a government engineer to whom he had shown his sketches. Once constructed, it was universally adopted, and is to-day practically the same as his original design.

His steam pile-driver did in four and one-half minutes what the old drop did in twelve hours and revolutionized the building of wharves, docks and foundations.

His inventive genius had a wide range. It included improvements in mechanics; applying steam power to canal traction; superheating steam; measuring expansion of solid bodies; method of casting composition; the flexible shaft; safety ladles for foundries; the invention of steam and torpedo rams; the wedge-shaped water valve; a hydraulic press; improved method of welding iron; the skew face punch for large work; hydraulic punch; upright form of engine; the turntable, trunnion vision telescope; link valve motion; method of drilling tunnels in rock; chilled cast iron shot; and preceded Bessemer with a process of steel making.

He had exceptional mechanical judgment. He saw the simplest way to a desired end, discarding unerringly all superfluous material and movements.

His inherited judgment of eye, his boyhood practice in handicraft, his early training under Maudsley gave him high rank as an engineer.

Beside these he made discoveries in astronomy, geology and archaeology. He traveled widely in Europe,

giving advice to government departments and was much sought in his own country for consultation on mechanical improvements in military and naval construction.

In his autobiography (from which these facts are taken), there is not a hint of personal or professional jealousy from cover to cover. Even when others appropriated his ideas without credit, he found only cause for satisfaction that his ideas were approved.

His genial, art-loving nature and enthusiasm made him a charming companion. His engineering skill, scientific attainments and ancestral connections gave him a wide range of social acquaintance in England and the Continent.

Having made a reasonable fortune from his business, he retired at the early age of forty-eight, to devote himself to his "hobbies," astronomy, art and invention.

In astronomy he was especially interested. His drawings of the moon and sun spots and discussions as to the nature of their surfaces awakened much discussion at the time among the best astronomers of the day. He painted some pictures that were valuable from the minute care given to details of architecture and furnishings. He also made interesting contributions in archaeology, especially as to the origin of cuneiform inscriptions. He died in 1890, aged eighty-two years.

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Alfried Krupp

1812-1887

Alfried Krupp.

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Extraordinary application and dogged perseverance explain the success of Alfried Krupp. He is an excellent illustration in history of the wisdom of the Nazarene's philosophy, "Go sell that thou hast . . . . and come, take up thy cross." Many a life of promise has come to nothing from scattering its forces. Alfried Krupp surpassed expectations by concentration and persistence.

His inheritance was fortunate. His father left him not wealth, but the spirit and incentive for severest toil. Blood and heredity told in his case as in few others. His ancestors were men of wealth and force. His great-grandmother bought an abandoned iron works and brought it to activity for a time. His grandfather was a successful merchant, but died young. His father was brought up by a capable mother and this energetic grandmother.

Although the larger iron works were disposed of, the father continued experiments to make cast steel. This was from 1800-1815, at the time when England alone had the secret of making steel. To make the situation worse, Napoleon's embargo cut off entirely the supply from all Europe. Alfried's father began with wealth. He is said to have been an austere man, of iron will, rendered gloomy from continued ill success. Little by little his wealth disappeared. He gave up his fine mansion to live in a

laborer's cottage beside his forge. After weary years he learned the secret of steel making, but it came too late; at the early age of thirty-nine he died of a broken heart.

Before he died he gave the secret of his steel to Alfried, who was then only fourteen years old, and willed that he assume at once, under the oversight of the mother, the management of the business.

That was his heritage, a memory of wealth followed by increasing cares and ever deepening poverty; a father devoted to what he thought to be his duty—single of aim, indomitable and persistent. The lines of these qualities were woven together in Alfried to make the fabric of his genius.

He was wise beyond his years, and, guided by his energetic mother, took up the burden his father had so wearily laid down, with a prospect only of hardest toil and small returns. For twenty-five years he worked unremittingly, by daylight at the anvil and forge, by lamplight at his accounts and books. For years he could hardly pay the wages of his men, let alone any profit to himself. After twenty-five years the clouds of care began to break away, and henceforth success came in almost geometric progression—the marvel of the world.

Alfried Krupp was born at Essen in 1812. In 1826 he began his life-work, with only two helpers, without experience, strength, capital or credit. At first he made tools, tanners' scrapers, mint dies and tools. He sought from the very first to make everything that he used himself, a course that he followed to the end, and that explains the wide ramification of the present industry at Essen.

His first noteworthy invention was a cast-steel roller die that he patented in Germany, France and England.

The sale of the English patent was the first reward worth mentioning that came to him. During these early years he made various journeys, working for longer or shorter times in other iron works, to increase his knowledge, spending some time in England, and always returning enriched by experience, which he at once put to use at Essen. He sought to become acquainted with technical experts and arrange for an exchange of experience.

In 1832 he had ten workmen, in 1845 he had 122 at work, which number fell off to 72 in the trying year of 1847-1848, but ever after this there was increase.

In 1844 Krupp received a gold medal for the excellence of his steel.

In 1845 he began to make cannon of cast steel that were of acknowledged merit, but were only looked upon as curiosities. In 1851 came the general recognition of his genius. In this year he exhibited at London a block of cast steel weighing two tons and a half. This was unprecedented, and placed Krupp at once at the head of the world's steel-makers.

It is to be remembered that hitherto steel had been made only in small crucibles. Bessemer's method came into use seven years later, and the Siemens open-hearth process still later.

Krupp ever after kept his lead in casting huge masses of steel. He invented a method for forging weldless car-wheel tires, and in 1857 made his first cannon on a government contract, for Egypt.

In 1861 he invented the breech-loading mechanism for cannon that was at once adopted by Prussia, and, following, by all civilized nations. This was an epoch mark in the history of the works.

While Krupp very early adopted the Bessemer pro-

cess for rails and structural material, and the Siemens process for armor, tires, cranks and axles, he always used crucible steel for his cannon, a choice that time wholly vindicated.

He steadily increased the capacity of his plant to produce and handle large and larger ingots.

In 1867 he exhibited a 14-inch gun weighing 10 tons, and later one weighing 60 tons, and still later a 120-ton.

During his lifetime he made above 20,000 cannon. To forge these huge masses he introduced great steam hammers and furnaces. His 50-ton hammer was for years the wonder of Europe.

His inventions covered almost everything in ordnance, firing mechanism, projectiles, gun carriages and armor plate, also many for the manufacture and working of steel for special purposes.

The characteristic of Krupp's work was always its magnitude—in product and capacity. This characteristic has been fully maintained by his son and successor.

His two helpers in 1826 were multiplied ten thousand fold in fifty years. His single forge had become a score of blast furnaces, hundreds of boilers, engines and hammers; thousands of furnaces and machine tools and miles of railroads. The little plant at Essen had sent out runners that had taken root in far distant places—mines for coal and iron, clay and limestone, smelting works, proving grounds and distributing centers, while his own steamships carried the product to the end of the earth. And the dogs of war were never loosed without barking from Krupp cannon, whether it be on the confines of Paris, the jungles of Africa or the lonely stretches of the great wall of China.

But the best of Krupp was his sympathy for his army

of workmen. His own trying apprenticeship in the school of life left him very solicitous for the comfort of others.

His first profits went to better their condition, and with the enlargement of the works came model tenements, co-operative stores, recreation halls, insurance benefits and old-age pensions.

Sometimes his efforts more than bordered on paternalism, but they were always genuine and loving. Alfried Krupp was sincere, modest and sunny. He preserved the old hut where he began life, and showed it with unaffected simplicity to the kings and great men who were his guests in later years. He was as proud of that as of his gigantic hammers, his glowing furnaces and his army of busy, contented workmen.

The true spirit of the man shows forth in the inscription he had placed on the walls of the old cottage where he began his work: "Fifty years ago this laborer's cottage was the refuge of my parents. May no workman of ours ever experience the sorrows that then enshrouded us! For twenty-five years the issue was in doubt, an issue which has since then, by degrees so astonishingly rewarded the privations, the struggles, the confidence and the perseverance of the past. May this example stimulate others in distress, may it encourage the respect for small domiciles and sympathy for the greater cares that often dwell therein.

"The goal of labor should be the common good, for that labor brings blessings, for that to labor is to pray.

"May each one of us, from the highest to the lowest, with like conviction strive to found and secure his fortune gratefully, modestly. Thus would my highest wish be fulfilled."

His son had been in control of the works some years before his death in 1887, when seventy-five years of age.

Charles Babbage

1791-1871

Charles Babbage.

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This short story will be divided into two parts, on account of the space necessary to describe, even in the briefest manner, the inventions of this most remarkable man. Very little is known about his home life, although he lived very recently; the invention so far transcended the man in importance, that the details of his life seem to have dropped out of sight.

Charles Babbage was born on the 26th of December, 1791, at Totnes, Devonshire, England. His parents were wealthy and sent him to a private school to be educated.

He entered Trinity College, Cambridge, in 1810. He early showed a marked interest in mathematics, and it is recorded that he was familiar with the works of the great mathematicians before he went to college. He graduated from Trinity in 1814 with high rank in mathematics, then traveled and continued his studies privately. His first published essay was on the Calculus of Functions, in the Philosophical Transactions of 1815. He was made a fellow of the Royal Society in 1816, and labored with Herschel and Peacock to raise the standard of mathematical instruction in England.

He early noticed the number and importance of errors in astronomy and other calculations due to errors in mathematical tables. The first idea of a calculating machine came to him in 1812 or 1813, while still a student.

Some years later he went to Paris to study their methods for computing and printing the now celebrated French tables of powers, roots, circumferences, areas, sines, tangents, logarithms, etc. There he met several of the most noted mathematicians of the day. He bought a copy, at a high price, of Didot's natural sines, carried to the twentieth place in figures. By the permission of the French officials, he copied by hand to the fourteenth place, from the tables of logarithms deposited in the Observatory, every 500th number from 10,000 to 100,000.

All scientific callings require these tables, but especially astronomers and navigators. These tables are now seen in every engineer's hand-book, and we little appreciate the labor and expense involved in their preparation. It is of interest to consider the extreme care that was taken to prepare them. The work of calculating these tables was entrusted at Paris to three corps of calculators, the first section investigated the various formulæ and selected the ones that could most readily be adapted to simple numerical calculation by many individuals. The second section consisted of seven or eight trained students, who converted the algebraic formulæ into numbers and tabulated and reviewed the calculations of the third group. The third section consisted of sixty to eighty persons, who simply added and subtracted the equations given them. Their labors occupied several years and the results were bound in 17 folio volumes. In these tables absolute accuracy is essential, and that is very, very rarely attained. In a set of logarithms stereotyped by Mr. Babbage, the proof was compared number by number with other tables seven times, nevertheless, in the last reading thirty-two errors were discovered. After stereotyping the proof was compared figure by figure four times and eight more er-

rors discovered. Other tables, after having been in use for years, have been found to contain hundreds of errors.

Becoming intensely interested in these tables and the methods for preparing and copying them, Mr. Babbage, as early as 1819, gave careful thought to the invention of a machine that would calculate and print them without the intervention of human hands and, therefore, without error. By 1822 he had made a small machine that would calculate simple formulæ, such as multiplication tables and squares up to eight figures.

In a letter of this same year to the President of the Royal Society, he not only describes this machine, but adds that he had already designed a method for printing faultlessly the results, and that he also had in mind machines to multiply, extract roots, and various other operations.

The machine that was constructed at this time was very simple, consisting of but few parts, but these were repeated many times. On trial, it was found possible to calculate from 30 to 40 numbers a minute, which was faster than a man could copy them down. He claimed that his machine only needed to be constructed on a larger scale to calculate any and all tables that were characterized by regular differences between succeeding terms, and to add printing mechanism that would produce and record absolutely faultless tables.

He called this first machine a Difference Engine, because it produced successive terms of a table automatically, by adding the requisite differences to the last term.

To illustrate in the table of squares, 1—4—9—16—25, etc.

By subtraction we get the first order of differences, 3—5—7—9, etc.

By subtraction again we get the second order of differences, 2—2—2, etc.

Now, to find any term, we have only to add the constant 2 to the last known difference of the first order to the last known square, to produce the following square:

To illustrate, what is the square of 11? The square of 10=100, the square of 9=81, 100—81=19 2+19+100=121, the square of 11. This is comparatively a simple table. There are tables in common use that have five, six, and even seven orders of differences, before the constant is found. Mr. Babbage, in 1822, wrote to the Prime Minister of England and asked Government assistance in constructing a Difference Engine that could calculate up to twenty places of figures, and that would also print automatically the results.

The Treasury referred the request to the Royal Society, for an opinion as to the merits of the invention. They reported promptly that it was "fully adequate to the attainment of the objects proposed by the inventor." Soon after, in 1823, the sum of $7,500 was appropriated to this end.

Mr. Babbage at once set to work to construct the enlarged and automatic Difference Engine. Draftsmen were set to work making the drawings. Mr. Joseph Clement. out of Maudsley's men, was given charge of the mechanical part, and for four years the work proceeded. Tools had to be designed and constructed to meet the demand for extreme accuracy, even workmen had to be trained to a nicety of execution before unheard of.

In 1827 the expense incurred had amounted to $17,000, of which Mr. Babbage had advanced nearly $10,000. At this time his health was poor and he went to Italy, leaving minute instructions to be followed in build-

ing the machine and placed $5,000 at their disposal. Perceiving that the probable expense would be considerable, he asked the Government for another grant. Lord Wellington inquired of the Royal Society for an investigation as to whether the project was worth proceeding with. The Society gave "their decided opinion in the affirmative." In 1829 the Government made another grant of $7,500. By this time the expense had reached $35,000. Lord Wellington then personally examined the machine, and the Government made a grant of $7,500 more, with the suggestion that the calculating part be separated from the printing device.

In 1830 still another grant of $15,000 was made by the Government. In 1832 the Government constructed a fire proof workshop near Mr. Babbage's residence to contain the costly drawings and machinery which had accumulated during the years. In 1833 a portion of the machine was put together, which completely justified the expectation. It could calculate, and did so with absolute accuracy, tables of three orders of differences up to sixteen figures.

Meanwhile difficulties arose between Mr. Babbage and Mr. Clement, who had charge of the construction. The latter had an increasing sense of the value of his part of the work, and his charges grew apace. At length Mr. Babbage secured consent to have Government engineers examine all accounts before being paid. There being some delay in paymets, Mr. Babbage was accustomed to advance money. In 1834, he declined to do this longer, and the result was that Mr. Clement withdrew, taking with him many of the best workmen and all the special tools that he had designed and built, which according to the custom of the day he had a right to do,

even though the Government had paid for them. Then there were vexatious delays, as to whether the Government would meet Mr. Clement's terms or secure some one else for the construction.

Meanwhile an entirely new idea came to Mr. Babbage by which he could construct a calculating machine of far greater range than the Difference Engine. Mr. Babbage felt that it was not right to ask the Government to complete the first machine without making known to them his new discovery. Perhaps also, and it would be quite natural, he rather hoped that the Government would abandon the old and start at once the construction of the new. At any rate, while the question was being discussed, political questions became involved and the matter was not decided until 1842, when it was definitely given up. The part of the machine that was completed was sent to the Museum of King's College, London, and later sent to South Kensington and the uncompleted parts distributed among friends and institutions, as souvenirs.

The entire cost of this machine to the Government, exclusive of the fire proof building, had been $80,000. Not one penny came to Mr. Babbage as a recompense for his labors of twenty years. In addition to what the Government had expended on the construction, Mr. Babbage had also expended fully as much more and considerable sums for personal expenses, experiments, travel, and research. Although this machine was never completed, it has been thought by some that the money had been well expended, because of the habits of extreme accuracy and precision that were introduced into English machine construction, by the many workmen and draftsmen who received their training under Babbage and Clement and

then passed on to other shops, carrying with them the skill and method there acquired.

The construction of machine tools was certainly greatly enriched by the necessities involved in the construction of this invention.

From 1828 to 1839, Mr. Babbage had been Lucasian Professor of Mathematics at Cambridge. He had made several journeys to the Continent and written many letters and essays. One book, published in 1834, called "The Economy of Machines and Manufactures," summed up his consideration of the manufactures of the time. This book was widely printed and read for several decades, and did much to extend the modern system of manufacture by machinery.

Once only, in 1832, he tried to enter public life, but was defeated.

The Analytical Calculating Machine.

It was not decided by the Government of England to discontinue the construction of the Difference Machine until 1842, almost ten years after work upon it had ceased. Meanwhile Mr. Babbage had given much thought and expense in perfecting his new and vastly more complicated calculating machine.

The Difference Engine was designed to calculate tables by simple addition of the proper differences. The Analytical Engine was designed to work out the algebraic development of any formula whose law was known and to convert it into numbers. In fact, Mr. Babbage declared that if constructed it could solve any algebraic problem the successive steps of which could be conceived

of by the human mind, do it automatically and print the result without the possibility of error.

In a letter Mr. Babbage thus describes it:

"It is intended to include 100 numbers, susceptible of changing—each may consist of 25 figures * * * any given function which can be expressed by addition, subtraction, multiplication, division, extraction of roots, or the elevation of powers, the machine will calculate its numerical value; it will afterward substitute this value in place of V or any other variable and will calculate the second function with respect to V; it will reduce to tables almost all equations of finite differences."

In the Difference Engine the exact method for adding was immaterial because a simplification of it only affected one or two hundred parts, but in the Analytical Engine, the mechanism for performing the elementary operations of adding, subtraction, dividing and multiplying became so important that any change affected thousands upon thousands of parts. In fact the machine could only exist by inventing for it a mechanical method of addition of the utmost simplicity. It is said that Mr. Babbage and his assistants designed and partly constructed over twenty different methods before the desired simplicity was attained.

The system of addition finally decided upon was extremely simple and yet it not only added all digits at once, but included in the total all amounts carried and what is more wonderful, had an "anticipating carriage," that included in the total all the amounts carried of the carryings. Thus any addition could be performed automatically at one operation, without the necessity of a subsequent operation to include the carryings.

The engine was not a combination of machines, the

one to add, another to subtract, another to divide, but was designed as one machine, so arranged that any operation, or any combination of operations, could be performed automatically at will. It consisted in the main of two sets of columns, the one called the mill and the other the store.

The mill consisted of a series of columns made up of discs, into which was placed the quantities about to be operated. The store consisted of a larger number of columns into which all the variables about to be operated upon were placed, and into which all those quantities, which had arisen by result of other operations were placed.

He thus separated the operations from the objects acted upon.

"All the shifts which have to take place, such as carrying, borrowing, etc.—changing addition into subtraction, or shifting the decimal place, are affected by a system of rotating cams, acting upon or actuated by bell cranks, tangs, clutches, escapements. These clutches and bell cranks control the process effected, or being themselves suitably directed, secure that the proper process should be performed on the proper subject matter and duly recorded or used as required."

The columns that make up the store contained a series of wheels that received the results of operations performed by the mill and served as a store of numbers yet to be used. The wheels gear into a series of racks, which in turn are operated by cards.

These cards were the new thought that came to Mr. Babbage when he was constructing the Difference Engine and which brought him visions of the possibilities of the new machine and led him to lose interest in the old.

The cards themselves were no new invention. They were invented by Jacquard to control the introduction of threads in weaving brocade. It flashed into Mr. Babbage's mind that he could use these cards to indicate successive operations in a calculating machine that, with this equipment, would have a power over complicated arithmetical operations that would be nearly unbounded.

These cards were perforated by different combinations of holes and were then linked together as a chain and arranged to pass successively over a set of wires. The wires, corresponding to the holes, would drop through and indicate by suitable connections the desired operations of the mill.

Having the machine, all that human brains are called upon to do is to perforate successive cards and then operate the machine, when the desired opeiations would follow without possibility of error.

In the Analytical Engine there were two principal sets of these cards, one to indicate operations, one to indicate the columns of variables upon which the results are to be presented.

These cards thus arrange the various parts of the machine and then execute the processes.

Illustration.

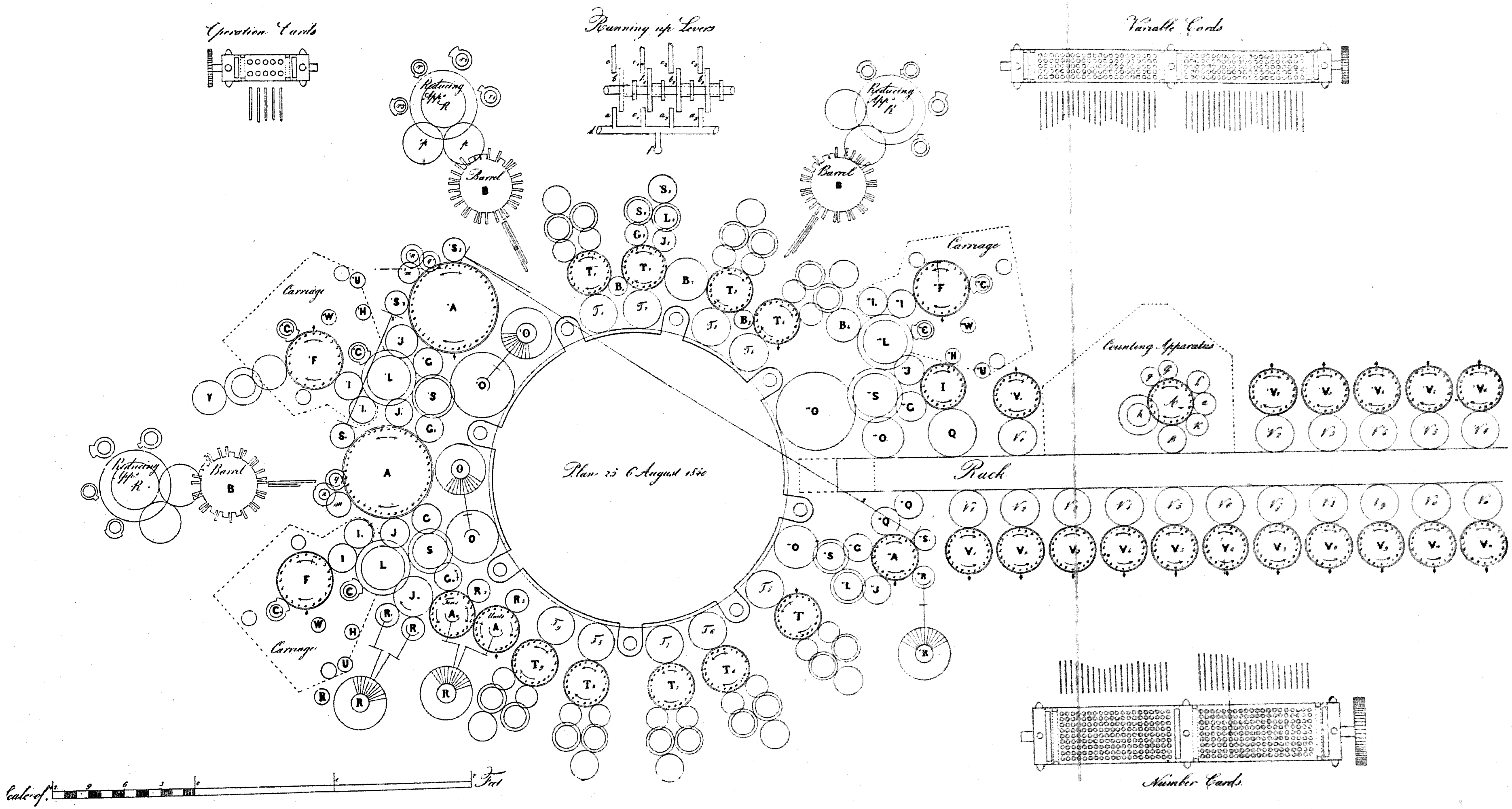
$$(1)\quad mx+ny=d$$

$$(2)\quad m'x+n'y=d'$$

$$(3)\quad x=\frac{dn - d n}{mn'-m'n}$$

$$(4)\quad y=\frac{d'm-dm'}{mn'-m'n}$$

To find the value of x and y eleven successive op-


Operation Cards
Running up Levers
Variable Cards
Reducing Appt R
Barrel B
Carriage
Counting Apparatus
Plan 25 6 August 1840
Rack
Number Cards
Scale of
Feet

erations must be performed, as indicated in the following tables:

Columns on which are inscribed the primitive data.	Number of the operations	Cards of the operations: Number of the Operation-cards.	Cards of the operations: Nature of each operation.	Variable cards: Columns acted on by each operation.	Variable cards: Columns that receive the result of each operation.	Variable cards: Indication of change of value on any column.	Statement of results.
$^{1}V_0 = m$	1	1	$\times$	$^{1}V_0 \times {}^{1}V_4 =$	$^{1}V_6$	$\{^{1}V_0 = {}^{1}V_0$ $^{1}V_4 = {}^{1}V_4\}$	$^{1}V_6 = mn'$
$^{1}V_1 = n$	2	,,	$\times$	$^{1}V_3 \times {}^{1}V_1 =$	$^{1}V_7$	$\{^{1}V_3 = {}^{1}V_3$ $^{1}V_1 = {}^{1}V_1\}$	$^{1}V_7 = m'n$
$^{1}V_2 = d$	3	,,	$\times$	$^{1}V_2 \times {}^{1}V_4 =$	$^{1}V_8$	$\{^{1}V_2 = {}^{1}V_2$ $^{1}V_4 = {}^{0}V_4\}$	$^{1}V_8 = dn'$
$^{1}V_3 = m'$	4	,,	$\times$	$^{1}V_5 \times {}^{1}V_1 =$	$^{1}V_9$	$\{^{1}V_5 = {}^{1}V_5$ $^{1}V_1 = {}^{0}V_1\}$	$^{1}V_9 = d'n$
$^{1}V_4 = n'$	5	,,	$\times$	$^{1}V_0 \times {}^{1}V_5 =$	$^{1}V_{10}$	$\{^{1}V_0 = {}^{0}V_0$ $^{1}V_5 = {}^{0}V_5\}$	$^{1}V_{10} = d'm$
$^{1}V_5 = d'$	6	,,	$\times$	$^{1}V_2 \times {}^{1}V_3 =$	$^{1}V_{11}$	$\{^{1}V_2 = {}^{0}V_2$ $^{1}V_3 = {}^{0}V_3\}$	$^{1}V_{11} = dm'$
	7	2	$-$	$^{1}V_6 - {}^{1}V_7 =$	$^{1}V_{12}$	$\{^{1}V_6 = {}^{0}V_6$ $^{1}V_7 = {}^{0}V_7\}$	$^{1}V_{12} = mn' - m'n$
	8	,,	$-$	$^{1}V_8 - {}^{1}V_9 =$	$^{1}V_{13}$	$\{^{1}V_8 = {}^{0}V_8$ $^{1}V_9 = {}^{0}V_9\}$	$^{1}V_{13} = dn' - d'n$
	9	,,	$-$	$^{1}V_{10} - {}^{1}V_{11} =$	$^{1}V_{14}$	$\{^{1}V_{10} = {}^{0}V_{10}$ $^{1}V_{11} = {}^{0}V_{11}\}$	$^{1}V_{14} = d'm - dm'$
	10	3	$\div$	$^{1}V_{13} \div {}^{1}V_{12} =$	$^{1}V_{15}$	$\{^{1}V_{13} = {}^{0}V_{13}$ $^{1}V_{12} = {}^{1}V_{12}\}$	$^{1}V_{15} = \frac{dn' - d'n}{mn' - m'n} = x$
	11	,,	$\div$	$^{1}V_{14} \div {}^{1}V_{12} =$	$^{1}V_{16}$	$\{^{1}V_{14} = {}^{0}V_{14}$ $^{1}V_{12} = {}^{0}V_{12}\}$	$^{1}V_{16} = \frac{d'm - dm'}{mn' - m'n} = y$
1	2	3	4	5	6	7	8

Cards for these variables must be arranged and cards for the eleven operations and then all that remained was to place the mechanism in motion. It is thus seen that anything in the way of calculating that the human mind is capable of precisely defining, this machine would be capable of performing.

Anyone at all versed in designing machinery will recognize the difficulties involved in keeping a clear conception of the individual motions of this maze, of "wheels within wheels." In order that he might have a clearer insight into the various motions, Mr. Babbage invented a system of mechanical notation, by means of which he

could chart the syncronous motions of every part of even the most complicated mechanism. The motion of each part was represented by a vertical line, whose length was divided into units of motion. On each side of this line were various symbols for direction, nature (intermittent or regular), source, etc. These tables of notation were carried to such refinement that in designing it was always possible by laying a straight edge across the chart to see at a glance the exact position and status of every part at that instant.

It is said that at one stage it was desirable to shorten the time in which a certain operation was performed. The constructor had a model of the part before him, while Mr. Babbage resorted to his tables. The operation required the time of twelve revolutions. After prolonged study, they found ways to reduce the time to eight revolutions, then the constructor gave it up, but shortly after Mr. Babbage discovered new combinations by which it was crowded into four revolutions.

For twenty years Mr. Babbage continued work on this invention in his own house and at his own expense. He continuously employed draftsmen and mechanics, and took much time in explaining his designs to visiting experts, mathematicians, and philosophers.

It was no dream of a crank. It was the consummate result of the life-long thinking of the greatest genius for this sort of thing that the world has ever seen. The designs were examined by the wisest philosophers and the foremost engineers of his day, who again and again gave commendation and endorsement to the worth of his plans.

To be sure, only a small part ot the mill was ever built, just sufficient to show the method of adding and

subtracting and the anticipating carriage. Part was made in gun metal mounted on steel, but the greater part of a kind of pewter hardened by zinc and moulded by pressure. All the principles were either drawn or constructed in models.

A great many experiments were made and special tools designed for making with sufficient precision the multitude of little wheels, which, in some cases, amounted to 50,000, and the various methods of construction were determined upon. Over 400 drawings were made, of which some thirty were group plans, some of which were of elaborate complication. There are five volumes of sketches, and 400 to 500 folio pages comprising a complete mechanical notation.

There was very little description made of it. The philosophers were more interested in speculation over its mathematical possibilities and Mr. Babbage was too busy designing until the infirmities of old age prevented him. He once, however, spoke of 1,000 columns with 50 wheels each in the store alone, and, besides, many thousand wheels mounted on axles in columns for the mill and a vast machinery of cams and cranks for the control.

It was a marvel of mechanical ingenuity and resource, in detail good, but, on the whole only a theoretical possibility. Probably no man but Mr. Babbage himself ever understood its working.

M. Menabrea, an Italian Military Engineer, made a profound study of it in 1842, but admits in his careful description that the time at his disposal was gone before he had begun to master its more abstruse possibilities.

The Analytical Engine was invented in 1834, and it was 1848 before Mr. Babbage felt that he had mastered its main design. In 1852 he consulted the Government

to see if they would construct it, and in 1854 he abandoned work upon it.

He had doubtless expended over $100,000 of his private fortune on the two machines. Those who were cognizant of the state of machine construction during these years aver that the money expended was more than repaid in the advance caused in the art of constructing machines of precision. No small credit should be given to Mr. Babbage for this exceedingly practical result of his painstaking efforts.

The printed works of Mr. Babbage comprise over 80 titles, nearly all of which are essays on mathematical and philosophical subjects. He died in London in 1871.

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Sir Joseph Whitworth

1803-1887

Sir Joseph Whitworth

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Carlyle defines genius as "an infinite capacity for taking pains." He was a friend of Sir Joseph Whitworth, and may have learned this definition from acquaintance with him, who was most patient and painstaking.

He was not at all versatile or ingenious, but rather studious, deliberate and persevering. His few inventions and many productions were all the logical sequence by induction from experience, experiment and careful study. He was born in 1803, son of a schoolmaster, and, after a fair education for the times, he went to work in a cotton mill when fourteen years old. At eighteen he ran away to Manchester and began his machine-shop practice. At twenty-one he went to Maudsley's, in London, the best machine shop of the day. In these days there were almost no machine tools, and nicety of workmanship was almost wholly dependent on the skill of the machinist.

Whitworth, with his exceptional training, recognized the necessity of fine machine tools if accurate workmanship was to be cheapened and expedited. He saw at once that machines could produce no better work than that which marked their own construction. He discerned that the plane surface was the basis of all excellence in machinery, and set himself to produce a plane surface as near perfect as possible. In 1830 he produced the first

set of really plane surfaces. The old method universally followed was to rub two plates together—his method was to produce as perfect a straight edge as he could and then use it to test the work of hand scraping. He made his first true planes when with Maudsley. From these the reproduction of plane surfaces was comparatively easy.

In 1833 he went into business on his own account in Manchester. To make these surfaces he designed the well-known planer that is to-day much as he originally made it. The "slide" principle involved in the planer and many other modern machines seems simple, and few are aware that its discovery as a mechanical movement is within the memory of men now living, and was dependent for its success upon the manufacture of plane surfaces with mechanical precision.

Whitworth next gave his attention to perfecting and standardizing the pitch of screws. Every manufacturer had his own shape and pitch, with resulting confusion. He made a large collection of screws and carefully selected standards. Then he set about making a perfect guide-screw, and kept at it for six months. It was thirty feet long, two threads to the inch. That for which he contended—a generally-accepted standard—is now accepted the world over.

In England the Whitworth standard is still in use, but in the United States the common 60° pitch with flattened top and bottom, has taken its place.

It is a great debt the mechanical world owes to Joseph Whitworth for the true plane, the slide and the screw. Much credit is also due him for his instruments for exact measurements. He made a standard yard, and his workshop measuring machine could distinctly gauge

to the forty-thousandth part of an inch. In another machine he made, the one-millionth part could be noted. So accurate was this machine that the heat of a finger-touch was found to be disturbing. At a time when "a bare thirty-second" was the smallest unit of measurement, his common use of ten-thousandths was certainly revolutionary.

Most of his important machine tools were invented and perfected between 1833 and 1850, and are the forerunners of the numberless machine tools of to-day. By 1851 he was counted the foremost machine constructor of his time.

The outbreak of the Crimean war brought a radical change in his affairs. The Government needed a large number of rifles, and found that it would require twenty years to make them by the old hand method. They asked Whitworth to make for them a complete set of special machine tools for their manufacture. He refused to do so unless they would first authorize him to make extensive investigations to know for certain the principles that conditioned the size, shape, pitch and proportions of bore, rifling and bullets. At first they thought it an unnecessary expense, but later permitted him to do so.

He erected a covered range with windows only on the south, a movable target and facilities for placing paper screens at regular distances across the whole range. Then he tested every combination of size, length and rifling of barrel; proportions of projectiles and charge of powder. After each he carefully measured the holes in the paper screens and noted in which the holes were clean cut and in line, in which and how often the projectile had turned over or gone in a spiral.

As a result of these elaborate experiments he es-

tablished as best the following proportions: Bore .45, polygonal rifling with a pitch of 1 inch to 20 inches, and a projectile whose length is 3½ times its diameter.

These proportions were embodied in the Whitworth rifle that proved itself vastly better than anything hitherto produced.

Many governments at once either purchased his rifles or adopted his standards and among private concerns his principles were universally adopted.

But British officialdom was too hide-bound to adopt it for long years afterward. In 1874 they adopted the Martini-Henry rifle as the standard, which was constructed on the general dimensions that Whitworth had proven to be correct twenty years before.

He believed that these same proportions held good upon cannon, and from 1860 to 1872 made many valuable improvements in proportions and shape of bore, and projectiles, composition of gun powder, rifling, and flat head projectiles for penetrating armor at angles and below the water line.

By 1860 he was manufacturing high-grade cannon having an unprecedented range. Being dissatisfied with the strength of steel usually employed for this purpose, he began experiments to improve the quality. After making 2,500 experiments, extending over six or seven years, he succeeded in making the best steel that was ever made for this purpose, namely, crucible steel, hydraulically compressed, when in a fluid state, under a pressure of six tons to the square inch. Where Krupp cannon had an average life of 600 to 800 shots, Whitworth cannon were fired, under the same conditions, 3,500 times without a single mishap. His great propeller shafts, cast hollow

and compressed, showed also the same high strength and uniformity.

In 1876 he produced an armor plate made up of concentric rings of compressed steel that exhibited greatly increased resistance.

In working out these results he designed a great variety of machinery, including the famous 8,000-ton hydraulic press for compressing ingots of fluid steel.

In all this work of a massive kind he showed the same carefulness and nicety that characterized his earlier work on machine tools and measuring instruments.

Sir Joseph Whitworth was impressed, as were many other thoughtful Englishmen, with the steadily decreasing prestige of British engineering. He saw the cause in her indifference to scientific and technical education, and to do his part toward improving the conditions, he set apart a fund of $500,000 to found a series of scholarships. This was in 1868, and to the end of his life, as one of the directors of this fund, he gave thoughtful and conscientious attention to its distribution. This fund was much appreciated by the nation, and had a far-reaching effect in increasing interest in scientific study.

He also endeavored to make the success of his works benefit his employees, and to this end incorporated his business, the shares being reserved entirely for himself, his foremen and workmen. It was made especially easy for his poorest workmen to acquire shares on credit. He required, however, that any one leaving his employ should sell back any shares he might hold, to the corporation.

Joseph Whitworth was always very careful to know what was right, and then had a strong and unbending will in holding to his conclusions. He was a man of simple

and healthy tastes, taking equal interest in engineering and his gardening.

He was a highly honored member of the leading scientific societies, before whom he presented some half dozen epoch-marking essays. He was honored by knighthood in 1869.

He died in 1887, leaving the bulk of his large estate to certain friends who were acquainted with his wishes, and who have, since his death, distributed no less than $3,000,000 to charitable and educational purposes.

Throughout his long life he faithfully illustrated a favorite motto:

"He is strong who is foresighted."

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Sir Henry Bessemer

1813-1898

Sir Henry Bessemer.

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The father of Henry Bessemer was a notable inventor even before the French Revolution. He was in the employ of the French mint and had been made a member of the Academy of Science at the exceptionally early age of twenty-five, and was a favorite of Robespierre. Through a misunderstanding he excited the frenzy of the mob, was arrested and jailed, but escaped to the shores of England.

Bessemer secured a position in the English mint, and his talents soon brought him enough money to buy a small estate at Charlton. Affter this his ingenuity had free scope, and to him are credited inventions in microscopes, and type-founding. This latter was a source of considerable profit, and together with a process for saving gold from the acids used for cleaning by the jewelers of his day, enabled him to bring up his children in some comfort. This inventive faculty was passed on to his younger son, Henry, in whom it was developed to such a degree that he came to be honored as the greatest inventor of his age.

Henry Bessemer was born in 1813 at Charlton, and there passed his childhood and youth. His mechanical genius was early recognized and fostered by his father, who gave him every facility and sympathy. As early as sixteen years of age he had mastered the intricacies of

geometric engravings. At eighteen he went to London, and easily supported himself as an engraver on steel, and a modeler in clay. At nineteen he exhibited at the Royal Academy. At twenty he invented an inexpensive and accurate method for reproducing any embossing or relief. So impressed was he with the opportunity for fraud if it became generally known that he decided to keep it a secret, and a secret it remained. Then, his mind being on seals and fraud, he invented a self-canceling stamp that so recommended itself to the Stamp Office that it was adopted, and Bessemer was made superintendent at £600 per year. Then Bessemer made a mistake. He explained it to the young lady to whom he was engaged to be married, who at once suggested the far simpler expedient of dating each stamp. Bessemer improved on the suggestion by inventing a system of movable dates that was at once adopted by the Stamp Office without as much as a "thank you" to the inventors. It saved the Government a half million dollars a year, and they showed their gratitude by forthwith dispensing with the services of Bessemer.

This was only the beginning of the shabby treatment which he received from the hands of the British Government, but it served one good turn. It cured him of giving his inventions away, and set him at work harder than ever to make up for lost time and money.

Next he invented a machine for making patterns for figured velvet that was so successful that the product was used to furnish the state apartments at Windsor. Following this was a type-casting machine, for which he obtained his first patent. It worked well, but was abandoned because of the opposition of compositors.

Then he turned his attention to the manufacture of

a bronze powder for gilding purposes. It took two years to accomplish this, but after that it was the financial foundation of all his after success. He locked the secret in the minds of only five trusty assistants, and the machinery was secured from prying eyes. As long as he lived they made gilt powder at enormous profit, at times making as much as a thousand per cent.

Then came a succession of inventions in the manufacture of paints and sugar, in the construction of railway carriages, centrifugal pumps, and ordnance, of apparatus for ventilating mines, and in a process for grinding plate glass. He was now forty years of age.

In 1853 came the beginning of the Crimean war, and Bessemer turned his thoughts to projectiles. He made inventions for firing and rotating elongated shot in the smoothbore guns of the day, but was simply pooh-poohed by the War Department. They never even tried them.

Being in France, and his inventions being talked about, he was sent for by the Emperor, who was so much pleased with his results that he gave him open credit to continue his experiments for the benefit of France. While thus engaged, he was convinced that the real need was for a stronger material for the guns themselves, and so turned his attention to the manufacture of a cheap steel. Steel at that time was made by the Huntsman crucible process, as it had been made for a hundred years, selling for £50 to £60 per ton, which was thought to be a reasonable price. With an output of 50,000 tons per annum, England was in control of the world's market.

Bessemer at this time knew nothing of metallurgy and was obliged to begin at the beginning. As usual he made a thorough study of the subject in all the books he could find, then from extensive visits to many of the best

iron works and then he secured a small iron shop at St. Pancras, London, which he fitted up and devoted wholly to his experiments. At first he merely sought for purer iron and after twelve months he secured this and cast and finished an experimental cannon that he sent to the Emperor of France, who encouraged him to continue.

To protect himself he took out a number of patents as his experiments developed, improvements, in which he specified many changes in the crucible process for making steel as well as for refining iron. After eighteen months (1855) the idea came to him that he might purify iron by using atmospheric oxygen.

His first experiment was with a laboratory crucible holding about ten pounds of iron and using a movable blow pipe. The result was the softest malleable iron. Samples were made and tested in every way by the experts at Woolwich Arsenal and found to be satisfactory. His patent was dated October, 1855. But this was not steel.

He feared that as he approached the state of pure iron he would not be able to secure a heat sufficiently high for his purpose, but made his preparations to test the process on a large scale. At first he built a large furnace to be filled with crucibles in each of which would be immersed a blast pipe. This was not altogether satisfactory and anxiety brought on a severe fit of sickness. As he lay on his sick bed he thought of working a crucible in which the air could be injected through the bottom.

On recovering health he designed and built apparatus for this purpose.

It was a circular vessel, three feet in diameter and five feet high, holding about seven hundred pounds. He secured a small but powerful air engine and after setting

it going ordered the molten iron poured in. To the surprise and consternation of everyone there came out a volcanic torrent of sparks and coruscations. The air cock for regulating the blast was near the furnace, but no one dared approach it; the cover of the furnace melted and disappeared, the chain which held it grew red, and then white-hot, but just then the sparks ceased—the fury was over—and when the result was tested it was found to be a good quality of steel.

He immediately patented the process—February, 1856.

The first public announcement was made in 1856. It excited great interest and eagerness to try on a large scale. Large royalties were paid for the exclusive use of the process, and costly attempts were made to use it, but strange to say, the experiments all went bad; the product was useless, and the process was declared to be a commercial failure.

The cause of the failure was learned afterwards by Bessemer himself. By mere chance his first and successful experiments were made with an iron remarkably free from phosphorus, while the later experiments, on a large scale, were all made with common iron, and the resulting metal, while remarkably free from carbon, was worthless from the excess of phosphorus.

At first he tried ways of eliminating the phosphorus, but finally decided that the best and cheapest method was to use raw material that was free from this impurity. The result was a success. Iron of 99.84 per cent. purity was made at a cost of less than one-sixth the cost of the nearest approach to it by the old method. But this was not steel. To this end Bessemer labored, and at last

found success in the addition of a little ferro-manganese at the end of the blow.

Heath had previously patented such an addition to ordinary steel as a means of utilizing a cheaper grade of raw material. Mushet held the early patents for its application to the Bessemer process, but Bessemer himself successfully defended his claim to independent discovery and practice. Bessemer's invention of the converter mounted on trunnions had an important place also in making the process a practical success.

Two years after the collapse of the first interest in the process, Bessemer completed his experiments, and again laid the result before the world. This time it awakened no interest, so he and his partners bought up the old licenses and erected a steel plant of their own. At first their only orders were for forty and fifty pounds. Little by little the orders increased, and the other steel-makers discovered that Bessemer was underselling them a hundred dollars a ton and still making an enormous profit. New licenses were granted at advanced rates, and the steel began to be generally made and used. By 1861 the transition from the Age of Iron to the Age of Steel was complete.

Bessmer is credited with 120 patents. Even after affluence came to him, the amazing stream of inventions continued, and for forty years, but a single year, 1866, went by without one or more patents in his name.

Bessemer was honored immediately by the leading scientific society of England with a gold medal, and later by the various learned societies of Europe.

The European governments promptly decorated him, all save his own country—England—that was benefited beyond all measure by his inventions. England snubbed

him for the third time by refusing to make any use of the steel that bears his name, and when France sought to bestow upon him the decoration of the Legion of Honor, objected.

Twelve years after the invention was made, and when England was the laughing-stock of the world, she finally adopted his process in her arsenals, and not until 1879 was the honor of knighthood tardily conferred upon him.

The year before his invention of steel-making was presented, England made 50,000 tons of steel at a selling price of $250 to $300 a ton. By 1882 the output had increased to 4,000,000 tons a year, which was selling for some $40 a ton, a saving of nearly $1,000,000,000.

A princely sum came to Bessemer in royalties and profits. He died in 1898 at the advanced age of eighty-five.

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Sir William Siemens

1823-1883

Sir William Siemens.

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Sir William Siemens was a great engineer. He was one of a family of eight boys, four of whom became famous. The father was a thrifty German farmer and a descendant of farmers. The parents dying in middle age threw the burden of the family on the eldest son Werner, "the Berlin Siemens," who was the real founder of the family. The latter was educated to be a soldier, but his strong liking for science and mathematics drew him more and more toward scientific pursuits. He became superintendent of the artillery workshops and later on was placed in charge of the introduction of government telegraphs and submarine mines.

In 1849 he left the army and with a Mr. Halske began business as manufacturing electricians. This firm became very famous for their inventions and the high quality of their product. This firm in co-operation with the brothers established large branch establishments at London, St. Petersburg, Vienna and Paris. Werner was highly honored by scientific societies and was raised to the nobility in 1888.

He it was who urged and made it possible for Charles William, the subject of this sketch, to devote himself to engineering.

Hans, the second son, became the head of a very

successful glass works in Dresden. Ferdinand became a prosperous farmer.

Frederick was the able assistant of William, and after the death of Hans, carried on the Dresden Glass Works to higher repute. After the death of William he took on his manufacturing interests also.

Carl was distinguished for the energy and practical skill with which he co-operated with his brothers. He became the head of the important branch works at St. Petersburg.

William Siemens, the seventh child, was born in 1823, and when fifteen went to a technical school near where Werner was stationed. Later he went to Göttengen to study science but by 1842 his schooling was ended and he was apprenticed in a machine shop. He was only nineteen but already was in correspondence with Werner about various inventions in which they had a mutual interest.

One of these was a process for electro-plating. It was decided to have William go to England to sell it if possible. He went and soon sold it for $8,000. This success so elated the brothers that the next year he was back in England trying to sell two other inventions, a chronometric governor for steam engines and a process for copying prints. Both were very ingenious but never amounted to much in practice. They valued them at $250,000 each, and when they failed to sell them, they attempted to operate them themselves but only succeeded in sinking all their own money and all they could borrow.

His first success had made William over sanguine, and it took three years of very trying experience to bring him to a better balance. These years were profitable,

however, in that they brought him into wide acquaintance with scientific men and large manufacturers. His prolific ingenuity was greatly developed and had become recognized. He now undertook various engineering commissions, and became interested in the application of heat in the arts, a department in which he afterward became an authority.

In 1847 he began experiments on a regenerative steam engine that busied him some years, and, although it was never made a commercial success, did effect in small units a considerable saving in full. The principle was to pass the exhaust steam through a chamber filled with wire gauze which became heated, and to pass the live steam through the same chamber, by which its temperature was raised from 250° to 650°. The same steam was then used over and over again, only enough new heat being added to make up for that which was transformed into power through the piston.

A number of regenerative engines were built, from five to forty horsepower, but they were never a success. His experiments, however, brought him steadily toward another application of the regenerative principle which was remarkably successful and which revolutionized heating furnaces.

While William was doing his best to make a success of the complex engine and evaporators, it occurred to Frederick in 1856 to apply the regenerative principle to the ordinary heating furnace. The brothers William and Frederick gave themselves up to this problem and made an immediate success of it.

The principle is simple. It consists in passing the waste products of combustion through a chamber filled with a checker work of fire brick which absorbs most of

the waste heat, which is then utilized to pre-heat the fuel and blast. Its advantage is twofold. By the direct combustion of fuel a temperature of 4,000 degrees only can be attained, but with the Siemens' furnace 10,000 degrees can easily be secured. It saves also from 50 to 80 per cent of the fuel necessary by the old process. A further improvement was made by William in the invention of the gas producer, in itself a very valuable invention, and the doing away entirely with solid fuel and ashes in the furnace itself.

The regenerative furnace is of equal value in all processes requiring heat, but has had its highest application in the manufacture of steel. The patent was granted in 1861, and in it he stated that it was specially applicable in melting steel on the open hearth. The next year he designed the first open hearth furnace, using this regenerative principle for a Durham iron maker who intended to make steel from wrought iron and spiegeleisen, but the process was not a success. Other experiments followed both in England and France, but were abandoned from lack of success.

Then Siemens erected his own steel works, principally for experimental purposes. The first furnace was for melting crucible steel in closed pots.

The second erected in 1867 was an open hearth furnace capable of melting a charge of 2,400 pounds every six hours, and was successful in producing steel from cast iron, and also directly from the ore. In May, 1867, the Great Western Railroad sent him a load of old iron rails to be made into steel. After some trials he did so and they were re-rolled as steel rails and used for many years.

Resulting from these successful attempts the Lon-

don Siemens Steel Co. was organized. This company intended to make steel directly from the ore and pig iron.

About this time the brothers Martin of France, licensees of Siemens, succeeded in making steel in the open hearth by simply melting wrought iron and steel scrap in a bath of pig metal.

This latter, known as the Martin-Siemens process, was the one generally adopted.

By 1867 the furnace had been well tested and applied with equal success to the manufacture of steel and glass and to other metalurgical operations.

In the years that followed he made elaborate experiments with a rotating furnace for making steel directly from the ore, but reached a commercial success.

Before this furnace was perfected, Mr. Siemens had invented the rotary water meter, and also some electrical devices, of which we will now speak.

It will be remembered that Werner Siemens, of Berlin, was deeply interested in electrical work and had established the shops of Siemens and Halske. The intimacy between the brothers kept William in touch with all the inventions of Werner, for whom he acted also as London agent. He had a small shop in London and made some minor electrical inventions himself. By 1853 he was made a full partner and the London shops were made a distinct branch under his sole charge. From this time on he began to undertake contracts for telegraph lines. At this time also the possibility of the submarine telegraph became known, and the Siemens Brothers being in the business from its conception became acknowledged authorities. Their work rapidly extended from the manufacture of instruments and

cable, to undertaking contracts for both land and submarine lines.

Mr. Siemens, in the years that followed, proved himself equally strong as an inventor, an engineer of construction, and as a promoter in securing franchises and capital.

The London branch became known as Siemens Brothers, and the work undertaken by them was on a very large scale, employing in the shops as many as three thousand men.

The most notable work undertaken by them was the construction of the Indo-European Telegraph, in 1867-1868, that involved raising an immense capital; diplomatic negotiations with Prussia, Russia, Turkey, Persia and India; building a duplicate line 2,750 miles long, including three submarine sections; passage across the unknown and inaccessible Caucasian Mountains, and through unsettled countries peopled by semi-civilized races. Siemens Brothers are to be credited also with laying four Atlantic cables.

The first Atlantic cable laid by Siemens was known as the Direct United States Cable and was successfully laid in 1874-1875. For this purpose Siemens designed the Faraday—an iron steamship of 5,000 tons, for the especial use of laying deep sea cables.

In 1856 Werner Siemens invented the first rotating magneto-electric machine. This Siemens armenture was the basis for the inventions of Wilde and Holmes, but it was not until 1866 that the two brothers Werner and William, working together discovered "the principle of electro-magnetic augmentation and maintainance of current without the aid of steel or other permanent magnets." This was the basis of all dynamo-elec-

tric machines, and the beginning of the modern use of electricity for lighting and power.

In 1867 William Siemens read before the Royal Society his now classical paper "on the conversion of dynamical into electrical force without the aid of permanent magnets." Two others discovered the same fact at almost the same time.

In 1872 the brothers Werner and Frederick invented one other device that completed in a general way, this most powerful of modern machines.

Other inventions of William were the pyrometer, for measuring high temperatures, the bathometer for measuring the depth at sea without sounding; improvements in steel armor plate, electric lighting, electric transmission and propulsion, smoke consumption; experiments in the growth of vegetation under electric light, and speculations on the source of solar energy.

By 1870 Mr. Siemens' habit of exhaustive study and scientific statement had become his dominant characteristic. He was recognized as an authority in electrical, heat and metalurgical engineering. He was a member and officer of many and various scientific societies. He had a fondness for scientific discussion, and his papers, and addresses were eagerly sought for by the various engineering societies.

He was honored by knighthood in 1883, and at his death in the same year with a memorial window in Westminister Abbey, contributed by his brother engineers.

As an engineer and in business he was a man of great versatility, energy and self-confidence, especially as to his money value. It is said that he made three fortunes, one he lost, one he gave away and one he kept.

Siemens.

As an inventor he was clear eyed, prolific and ingenious. His were not sporadic ideas but were the mature and complex results of patient and scientific consideration. Some came to little in practice, but all were admirable and theoretically correct.

As a man he was ambitious and of rather an excitable temperament, but kindly and benevolent, without a shade of jealousy or pride.

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